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Individual differences in the use of physical dimensions to classify matrix patterns

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INDIVIDUAL DIFFERENCES IN THE USE OF PHYSICAL DIMENSIONS TO CLASSIFY MATRIX PATTERNS.

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TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Individual Differences In the Use of Physical Dimensions to Classify Matrix Patterns.

A method was developed to study individual differences in the classification of matrix patterns which were controlled on five physical dimensions: % Black, Area, Second Moment of Inertia, Product of Inertia, and Matrix Grain. The method permitted a test of whether the findings of the study, based on the sample set of patterns, could be generalized to the stimulus domain.

Results from two experiments, each involving ten subjects, showed that individual differences did occur in processing the patterns. The controlled dimensions were used as the basis of classification. The dimension of % Black was descriptive of both the mean and modal basis of classification. However, classification was also made on the basis of the other controlled dimensions. Subjects were found to shift the basis of their classification over time. Most subjects formed an hypothesis concerning the basis of their classification before seeing all patterns at least once. The results were generalizeable to the stimulus domain.

An hypothesis feedback model was proposed to describe the results. Implications of the significance of the % Black dimension were suggested for such related areas as simultaneous discriminination tasks, reversible figures, possible physiological basis, and information theory ap-

proaches to pattern perception.

INTRODUCTION

The Attneave & Arnoult study (1956) is a major turning point in the study of form perception. The article established a basis for the quantitative investigation of physical variables that might be involved in the perception of forms or patterns. It also called attention to the previously unexamined problem of the stimulus domain.

> ".... the problem of drawing a sample of stimuli from a parent population characterized by certain determinate statistical parameters. The stimulus-domain includes all those stimuli to which the results may be generalized ...."

By 1965 the resultant proliferation of physical variables that had been investigated mandated that Michels & Zusne (1965) first classify these suspected form parameters before they could attempt to discover any common unifying aspects inherent in them. Three classes of parameters were defined: 1. Transitive, where changes in the magnitude of a parameter cause the pattern to belong to a different stimulus domain (e.g., Measures of redundancy and uncertainty). 2. Transpositional, where changes in the parameter cause a change in the representation of the pattern at the retina, but do not change the physical structure of the pattern itself (e.g., rotational and size transformations). 3. Intransitive, where changes in a parameter cause a change only in physical structure (e.g., perimeter, shape, area). Most parameters investigated fall into the third category. For this intransitive class, Michels & Zusne believe that the parameters are related through a set of mathematical moments, and that a measurement system based on moments is sufficient to describe form.

Brown & Owen (1967) state that the lack of a systematic knowledge of the stimuli used in form perception has been most damaging to the programmatic study of perceptual processes and suggest that a study of measurement and sampling procedures used with the stimuli is essential to the further development of a psychophysics of form perception. They argue that form is a multidimensional variable and that the sampled pattern to be used in an experiment must be representative of the stimulus domain.

Brown & Owen suggest that factor analyses is the proper approach to use in the study of form perception and that factorial designs are inappropriate due to the high intercorrelations of many of the physical form measurements. They argue that such intercorrelations create difficulties for factorial studies and that to avoid such problems factorial designs use only those stimuli which assure independence between measures in the sample set; they state that such stimuli are fixed factors whose results are not generalizeable to the stimulus domain.

In any experiment, regardless of statistical design, it is actually the stimulus domain that is under the control of the experimenter. A stimulus domain is described by the physical dimensions used to construct it; the problem of highly correlated physical dimensions need not occur. The stimulus domain can be constructed only from those dimensions which are known to be uncorrelated. Dimensions which appear to be independent based on experimental evidence may be used with discretion until statistically shown otherwise. The physical dimensions must be considered as being fixed factors. A pattern is a set of values, one from each of the controlled dimensions. Many physically distinct shapes or forms are in fact described by the same set of dimensional values. If a stimulus pattern used in a sample has been selected randomly from a set of stimulus patterns all having the same dimensional values, the sample stimulus pattern must be considered as a random factor. The property that two or more physically distinct stimuli may have the same dimensional values enables an error estimate to be obtained and a test of the goodness of representation of the stimulus domain by the stimulus sample to be made.

If one accepts the view that form is a multidimensional stimulus and that the perceptual system is subject to the effects of memory, motivation, and learning, differences in perceptual processing should be expected to occur among individuals and within an individual over time. However, the processing of patterns is usually assumed to be invariant. Silver et. al. (1966) using a similarities judgment task and performing a factor analysis concluded that individual differences were involved in processing on the basis that not all subject performance could be described by the same dimensions. Silver et. al. recognized the possibility that their stimulus sample may have been biased, leading Stenson (1968) to replicate the Silver et. al. study using an apparently unbiased sample. When the amount of variance associated with each dimension was estimated, Stenson found that four dimensions accounted for most of the variance over all subjects. He concluded that there were no wide differences between individuals. In referring to his and the Silver et al study, Stenson states

> "The point to be made from these two sets of results is that there are apparently a fair number of different strategies employed by Ss when they are asked to make similarities ratings. Thus, it is possible that studies of similarity in which data are averaged over all Ss produce results representative of no individual S."

It appears that factor analysis, while affording an investigation of many physical dimensions, does not provide a clean method for investigating individual differences in perceptual processing and may actually produce non-representative results concerning the processing.

A factorial design employing a classification task appears capable of providing an insight into the perceptual processing of patterns. In pattern perception the concepts of recognition and classification are usually used interchangeably (Neisser, 1967); however, Sayre (1965) makes the distinction that recognition is an instantaneous event whereas classification is a function of time. Handel (1967) states that in a classification task, a subject splits a set of multidimensional stimuli into discrete groups, the number of discrete groups being constrained by the experimenter. Intuitively, a classification task appears desirable in studying the emergence of differences in processing of patterns which are controlled over several dimensions. In a dichotomous classification task, if each of two resultant sets of stimuli is based upon each of two values of a bi-valued physical dimension, the psychological process of classification will be assumed to have been made on the basis of that physical dimension. Due to the nature of a more or less uniform physiological system it should be expected that many subjects will use the same dimension or dimensions as the basis of classification such that the dimensions will be representative of the average classification process. Unless an effort is made to control for the effects of memory, motivation, and learning, it should also be expected that not all subjects will operate on the average dimension. Similarily, changes in the basis of classification might occur over time. The nature of such changes, either an active shift over dimensions by the subjects or random, spontaneous shifts, remains to be determined.

The stimulus domain is limited by those dimensions used in its construction. In this initial study it was decided to limit the domain to the simplest type of form, a matrix pattern where a cell can be in one of two states: black or white. Polidora (1967) has pointed out that any theory of pattern perception must not only account for the perception of complex forms but also of the simplest. Dimensions which have been shown to have some effect on perceptual processing of matrix patterns were controlled.

Garner (1962) has stated that regardless of the nature of a pattern, an observer primarily responds to the maximum uncertainty of the pattern. Maximum uncertainty, U_{max}, is determined by the number of patterns in the universal set:

$$U_{max} = 2^c$$

where c = number of cells in a matrix

2 = number of states for each cell

A response made to U_{max} is completely confounded with a response made to the matrix grain; nevertheless, a sufficient number of experiments have been performed (See Garner, 1962, Chapter 6) to indicate that U_{max} or matrix grain may be an important dimension.

The role of redundancy as a pattern variable appears to have become doubtful through diversity of meaning. Evans (1967) has shown that redundancy may be conceptualized in three different ways, depending on the assumptions that one entertains. As such redundancy offers more information about the experimenter than about pattern perception. Redundancy has been associated with rules for sampling patterns from the stimulus domain, although the specific effect of such sampling rules on redundancy depends on theoretical viewpoint (Evans, 1967). Regardless of redundancy, the sampling rule for obtaining patterns from the domain, per se, may be an important dimension. Two sampling rules have generally been investigated; 1.) Selecting patterns which are only "random" or 2.) Selecting patterns which are "symmetrical about an axis" (Eisenman, 1967; Schnore & Partington, 1967; Foulke & Warm, 1967; Warm & Foulke, 1968).

Michels & Zusne (1965) have proposed that a system based on the moments of inertia of a pattern can adequately describe that form. There appears to be evidence for the second moment of inertia as a form parameter, and for a similar measure of dispersion of a form's area from its centroid, P^2/A (Arnoult, 1960; Zusne, 1965; Stenson, 1966; Behrman & Brown, 1968).

Michels and Zusne (1965) report only three studies where area, per se, was investigated as a form parameter; they state the common procedure is to control area over forms and to regard it as being of secondary importance. Smith (1969) points out that studies have shown equal areas to be perceived differently when form is varied. "Stretched out" figures were perceived as larger than others of equal area. Baird et al (1969) found a relation between apparent area and estimated complexity of a pattern. Bowen & Erikson (1969) found that an increase in area increased the rate of detection while increase in perimeter resulted in small or negligible increase in detection rate. Elias (1967), working with the hooded rat, showed that both "pattern area" and "background area" taken together could be related to efficiency of discrimination. In a matrix pattern, area can refer to either total area, as defined by the matrix perimeter, or to the percentage of the pattern that is either white or black.

This study investigated the following:

1. Whether individual differences occur in the processing of patterns.
2. Whether the results of the study can be generalized to the stimulus domain, as defined by the controlled dimensions.
3. Whether changes occur in the classification process over time.
4. Whether subjects shift dimensions over time.
5. Whether any of the controlled dimensions: % Black, Perimeter, Second Moment of Inertia, Matrix Grain (Uncertainty), or Product of Inertia (Symmetry) can be used as a basis of classification by subjects.
6. Whether any of these physical dimensions are descriptive of average classificatory behavior.

METHOD

Stimuli

Matrix patterns were used; each cell of which was limited to one of two states: black or white. The lines forming the boundaries of each cell, the matrix grid, were not shown on the patterns, although the perimeter of the matrix was. The pattern took on the appearance of a collection of black and white squares contained within a square boundary. Five physical dimensions were controlled on each pattern. Ninety-six patterns were used, two at each of the forty-eight factorial levels required by the design.

The physical dimensions that were controlled and the levels of each dimension are detailed:

1. Matrix Grain: Either a 4 x 4 or 6 x 6 matrix grid was used to design the patterns. For a constant value of perimeter, the effect of different matrix grains is to cause a difference in the size of each individual cell contained within the perimeter.
2. % Black: This dimension refers to the number of cells in the black state. Two levels of % Black were used: 25% and 75%. This corresponds to 4 and 12 black cells in a 4 x 4 matrix and 9 and 27, in a 6 x 6. However, the dimension of Product of Inertia precluded having an odd number of cells in one state for an even matrix grid; therefore, for the 6 x 6, 8 and 26 black cells corresponding to 22.2% and 77.7% were used. In discus-

sing this dimension the levels will be referred to as Low and High % Black.

3. Perimeter Size: Matrices used were either 1 in. sq., 2 in. sq., or 4 in. sq. The ratio between two successive sizes is constant. Perimeter size in conjunction with % Black makes possible a post hoc test of the effects of total amount of retinal stimulation, if necessary.

4. Second Moment of Inertia, I: As used in this experiment, this dimension refers to the dispersion of black cells in relation to the centroid (the center of gravity of a homogeneous area, defined by the first moment of the area with respect to the x-axis and to y-axis). Two levels of I, I_{lo} and I_{hi}, were defined and controlled on the patterns.

I must always be found with respect to either the x or y axis.

$$I_x = \int y^2 \, dA \qquad I_y = \int x^2 \, dA,$$

where x (or y) is the distance to the y (or x) axis about which the moment is taken. Knowing I_x implies nothing about I_y, and conversely. A measure of dispersion in both directions can be found by a transformation to polar coordinates. The polar moment of inertia is defined with respect to the origin.

$$I_o = \int r^2 \, dA$$

where r is the distance from the elemental area to the pole (Beer and Johnson, 1965). Noting that $r^2 = x^2 + y^2$, the following is true

$$I_o = \int r^2\, dA = \int (x^2 + y^2)\, dA = \int y^2\, dA + \int x^2\, dA = I_x + I_y$$

This measure, I_0, indicates the amount of dispersion about both centroidal axes.

As can be seen from the above equations, I is based on both area and distance; an identical pattern drawn on matrices of the same grid size but of different perimeters would of necessity have different values of I, even though, in relation to other features of the pattern, I is identical over both patterns. To have I_{lo} and I_{hi} reflect only differences in dispersion from a centroid and not differences in measurement values over patterns, the following procedure was used.

A rectangular coordinate system was defined such that the centroid of a matrix, defined by its perimeter, was at the origin. Each x and y axis was graduated in equal, non-dimensional units such that each matrix boundary was represented by a value of either $\pm$ 4, with respect to the origin.

Given the % Black level and the Matrix Grain level, the maximum possible amount of dispersion, $I_{o(max)}$, and the minimum possible amount of dispersion, $I_{o(min)}$, can be found. From these values the median amount of dispersion, $I_{o(med)}$, can be obtained for each condition (Table 1a.).

$$I_{o(med)} = (I_{o(max)} - I_{o(min)})/2) + I_{o(min)}$$

Then by definition,

Table 1a.

Median Values of I for each combination of Matrix Grain and % Black

% Black		Matrix Grain: 4x4	Matrix Grain: 6x6
% Black	Low	$90.7\ u^4$	$154.8\ u^4$
	High	$272.0\ u^4$	$521.5\ u^4$

Table 1b.

Range of Values of I for the Two Levels of I at each combination of Matrix Grain and % Black

	Low % Black		High % Black	
	4x4	6x6	4x4	6x6
I_{lo}	$42.7<I<90.7$	$41.1<I<154.8$	$224.0<I<272.0$	$407.8<I<521.5$
I_{hi}	$90.7<I<138.7$	$154.8<I<268.6$	$272.0<I<320.0$	$521.5<I<635.2$

$$I_{lo} = I_o < I_{o(med)}$$

$$I_{hi} = I_o > I_{o(med)}$$

To avoid ambiguity, all patterns in which $I_o = I_{o(med)}$ were not used; the range within which each value of I_o fell for I_{lo} and I_{hi}, for the different combinations, is given in Table 1b.

5. Product of Inertia, P_{xy}: The product of inertia is defined as:

$$P_{xy} = \int xy \, dA \qquad \text{(Beer and Johnson, 1965)}$$

It is obtained by multiplying each elemental area, dA, by its coordinates, x and y, and integrating over the area. Pxy has the property that when either one or both of the axes is an axis of symmetry for an area, $P_{xy} = 0$.

Two levels of P_{xy} were controlled in these patterns: $P_{xy} = 0$, symmetrical patterns; and $P_{xy} \neq 0$, non-symmetrical patterns.

The patterns were designed by having a number randomly assigned to each cell of a matrix; those cells whose numbers were then drawn from a random list were placed in the black state. If all the constraints imposed upon a pattern by a particular factorial combination of the controlled dimensions were fulfilled, a pattern was accepted for the sample set.

The patterns were drawn on posterboard with the aid of a template on which the design of the pattern had been perforated; the perimeter and the black cells were darkened with India ink. The patterns were photographed with a

Honeywell Pentax camera using high contrast copy film. The patterns seen by the subjects are shown in Appendix A.

Subjects

10 male volunteer students, attending Lehigh University summer sessions, were used in each of two experiments; the 20 subjects were paid $1.50 per hour.

Procedure

Subjects were run individually in a darkened, sound protected room. They were seated approximately 30 in. in front of a translucent panel; a box containing two push keys, one of which was labeled "Group A" and the other "Group B", was placed on a table in front of the panel. The patterns were projected onto the panel from an adjoining room, which also housed the electronic recording equipment. On each of four daily sessions a subject was presented with five random sets of the 96 patterns; four of the random orderings were different, with the last set always having been presented first. Each pattern was seen a total of 20 times in the course of the experiment.

A trial consisted of the subject being presented with a pattern and his classification of it into either "Group A" or "Group B". All patterns were presented successively with a 4 sec. blank interval from the time a subject made a decision until he was presented with a new pattern. The viewing time of each slide was held constant at 50 msec. through a Lafayette tachistoscopic shutter operated by a Hunter timer; the brightness level of the tachistoscope was set at dim. The fast viewing time was used to eliminate the possibility that any differences in classificational basis or in individual processing was a consequence of differential viewing times or of differential eye movements; Gould (1967) has presented evidence showing some relations between eye movements and predictability of dimensions.

Upon entering the experimental room, subjects were read the following set of instructions:

> I am going to present to you patterns composed of black and white squares for a very brief duration of time. Your task is to inspect each pattern that is presented to you and then place it into either Group A by pressing this button (experimenter pointed to appropriate key), or into Group B by pressing this button. The buttons need only be pressed gently.
>
> You are free to place the patterns into the two groups on any basis that you wish. If you have no questions we will begin.

Two experiments were performed; the position of the patterns in Exp. II were oriented ninety degrees counterclockwise from that shown for Exp. I in Appendix A.

Experimental Design

A mixed model, factorial design with nested factors was employed; this design can be expressed as:

$$YJKLM = \mu + a_j + \beta_k + c_{l(k)} + \delta_m + a\beta_{jk} + ac_{jl(k)} + a\delta_{jm} + \beta\delta_{km} + \delta c_{ml(k)} + a\beta\delta_{jkm} + a\delta c_{jml(k)}$$

a_j represents the effect of subjects, a random factor, 10 subjects were used in each of two experiments.

β_k represents the effect of the controlled physical dimensions. Five dimensions were controlled on the patterns; there were two levels of four dimensions and three levels of a fifth.

$c_{l(k)}$ represents the effect due to individual patterns. It is a random factor and nested under β. 96 different patterns were used; 2 at each of the 48 factorial combinations of β.

δ_m represents the effect of the daily session; it is a fixed factor. Four identical daily sessions were run in the experiment.

The theoretical mean squares and associated degrees of freedom are presented in Table 2. Quasi F ratios (Winer, 1961) were developed to test those terms, β, δ, and $\beta\delta$, for which no appropriate error terms existed.

Planned comparisons can be made for any test involving β; this enables a test for the significance of each of the controlled dimensions to be performed. Such comparisons do not involve all of the degrees of freedom of the β term; the remainder represent comparisons that can be made to test interactions between dimensions. The significance of one of these tests would indicate that different dimensions were used to classify different subsets of patterns. It will be assumed that the size of a subset involved in such interactions is equal to one pattern, and that all dimensions are equally likely to be used; that is, a "Random Dimension"

Table 2.

Theoretical Mean Squares and Degrees of Freedom for the Factors in the Experimental Design

Factor	Theoretical MS	df
Subjects (a_j)	$\sigma_e^2 + KMN\sigma_a^2 + MN\sigma_{ac}^2$	(J-1)
Dimensions (β_k)	$\sigma_e^2 + JLMN\sigma_\beta^2 + JMN\sigma_c^2 + LMN\sigma_{a\beta}^2 + MN\ _{ac}^2$	(K-1)
Patterns $(c_{l(k)})$	$\sigma_e^2 + JMN\sigma_c^2 + MN\sigma_{ac}^2$	(K-1)
Sessions (δ_m)	$\sigma_e^2 + JKLN\sigma_\delta^2 + KLN\sigma_{a\delta}^2 + JN\sigma_{c\delta}^2 + N\sigma_{ac\delta}^2$	(M-1)
<u>S</u>xD $(a\beta_{jk})$	$\sigma_e^2 + LMN\sigma_{a\beta}^2 + MN\sigma_{ac}^2$	(J-1)(K-1)
<u>S</u>xP $(ac_{jl(k)})$	$\sigma_e^2 + MN\sigma_{ac}^2$	(J-1)(KL-K)
<u>S</u>xSe $(a\delta_{jm})$	$\sigma_e^2 + KLN\sigma_{a\beta}^2 + N\ _{ac\beta}^2$	(J-1)(M-1)
DxSe $(\beta\delta_{km})$	$\sigma_e^2 + JLN\sigma_{\beta\delta}^2 + JN\sigma_{c\delta}^2 + LN\sigma_{a\beta\delta}^2 + N\sigma_{ac\delta}^2$	(K-1)(M-1)
PxSe $(c\delta_{l(k)m})$	$\sigma_e^2 + JN\sigma_{c\delta}^2 + N\sigma_{ac\delta}^2$	(KL-K)(M-1)
<u>S</u>xDxSe $(a\beta\delta_{jkm})$	$\sigma_e^2 + LN\sigma_{a\delta\beta}^2 + N\sigma_{ac\delta}^2$	(J-1)(K-1)(M-1)
<u>S</u>xPxSe $(ac\delta_{jl(k)m})$	$\sigma_e^2 + N\sigma_{ac\delta}^2$	(J-1)(KL-K)(M-1)

Legend:

J = Total Number of Subjects
K = " " " Dimensions Combinations
L = " " " Patterns at each Combination
M = " " " Sessions
N = " " " cells in design

<u>Values</u>

J = 10
K = 48
L = 2
M = 4
N = JKLM = 3840

will be assumed.

RESULTS

The frequency of classification of a pattern into either group was determined from daily subject protocols and expressed as a percentage. An analysis of the protocol for only one group must be performed, the other being complementary. However, choosing all "Group A" or "Group B" protocols would not be proper since no instructions were given as to which values to classify into either group; for example, two subjects could both use % Black as the basis for their classifications, but one might classify Low % Black patterns as Group A while the other might classify High % Black patterns as Group A. To correct for such occurrences, that group, either "A" or "B", for which the frequency of classification of each of the two patterns for the factorial combination 00000 (See Appendix A) was less than 50% was used in the analysis. If either of the two patterns were not classified into the same group with a frequency of less than 50%, the decision was based on the two patterns in the combination 00001. Seventy out of eighty protocols over both experiments were classified by the first decision rule, and the remainder, by the second.

Experiment I

The results of the analysis of variance for Exp. I are shown in Table 3. There was no significant effect due to individual differences between patterns. This result suggests that the findings of this experiment should be generalizable to other patterns in the stimulus-domain.

Table 3.

Results of Analyses of Variances for Experiment I

Factor	SS	df	MS	F or F'' (*)		P
Subjects	6.93	9	0.77	37.92	(9, 432)	p<.001
Dimensions	494.51	47				
% Black	486.92	1	486.92	*57.27	(1, 9)	p<.001
Area	0.42	2	0.21	* 0.38	(2, 18)	
Inertia	0.14	1	0.14	* 3.06	(1, 9)	
Pr. of I	0.62	1	0.61	* 0.95	(1, 9)	
M.G.	3.52	1	3.52	* 0.99	(1, 9)	
Random	2.90	41	0.07	* 0.99	(41, 378)	
Patterns	0.98	48	0.20	1.01	(48, 432)	
Sessions	1.16	3	0.39	* 1.93	(3, 31)	
<u>S</u> x D	151.08	423				
<u>S</u> x%B	76.33	9	8.48	417.81	(9, 432)	p<.001
<u>S</u> x Area	10.41	18	0.57	28.48	(18, 432)	p<.001
<u>S</u> x I	0.29	9	0.03	1.61	(9, 432)	
<u>S</u> x Pr I	5.82	9	0.64	31.84	(9, 432)	p<.001
<u>S</u> x MG	31.71	9	3.52	173.54	(9, 432)	p<.001
<u>S</u> x R	26.53	369	0.07	3.54	(369, 432)	p<.01
<u>S</u> x P	8.77	432	0.02			
<u>S</u> x Se	5.34	27	0.20	10.42	(27,1296)	p<.001
D x Se	4.74	141	0.03	* 1.10	(346,1106)	
P x Se	1.80	144	0.01	0.66	(144,1296)	
<u>S</u> x D x Se	44.96	1269	0.03	1.86	(1269,1296)	p<.001
<u>S</u> x P x Se	24.62	1279	0.02			

Note: * indicates F"

The very strong subject effect, significant beyond the 0.001 level, indicates that individual differences do affect the processing of patterns.

The Subject x % Black, Subject x Area, Subject x Product of Inertia, Subject x Matrix Grain interactions were all significant beyond the 0.001 level; the Subject x Random interaction was significant at the 0.01 level; only the Subject x Inertia interaction was not significant. These results imply that at some time during the experiment, the dimensions of % Black, Area, Product of Inertia, Matrix Grain, and Randomness were used as the basis for classifying patterns. However, only the dimension of % Black was significant over all subjects ($p<0.001$).

Theoretical protocols which result from using a particular controlled dimension as the basis of classification can be generated for the factorial combinations of Appendix A; these protocols are presented in Table 4. Each daily subject protocol, obtained by combining the frequencies for both patterns in the same factorial combination, was compared to each theoretical protocol through a chi-square analysis. Unless there is near perfect agreement between a theoretical and an obtained protocol, the possibility exists that more than one theoretical protocol may significantly describe an obtained protocol. However, the chi-square, being directly proportional to the Fourfold Point Correlation coefficient (Phi Correlation Coefficient), also indicates which theoretical protocol best describes the

Table 4.

Idealized Stochastic Dominant Protocols for the Five Dimensions with I Representing a Frequency Greater than 50% and 0, a Frequency Less Than 50%. The Sequence of Factorial Combinations is that Given in Appendix A.

Table 4.

	% Black	Area			Inertia	Pr. In	M. G.
1	0	0	1	1	0	0	0
2	0	1	0	1	0	0	0
3	0	1	1	0	0	0	0
4	1	0	1	1	0	0	0
5	1	1	0	1	0	0	0
6	1	1	1	0	0	0	0
7	0	0	1	1	1	0	0
8	0	1	0	1	1	0	0
9	0	1	1	0	1	0	0
10	1	0	1	1	1	0	0
11	1	1	0	1	1	0	0
12	1	1	1	0	1	0	0
13	0	0	1	1	0	1	0
14	0	1	0	1	0	1	0
15	0	1	1	0	0	1	0
16	1	0	1	1	0	1	0
17	1	1	0	1	0	1	0
18	1	1	1	0	0	1	0
19	0	0	1	1	1	1	0
20	0	1	0	1	1	1	0
21	0	1	1	0	1	1	0
22	1	0	1	1	1	1	0
23	1	1	0	1	1	1	0
24	1	1	1	0	1	1	0
25	0	0	1	1	0	0	1
26	0	1	0	1	0	0	1
27	0	1	1	0	0	0	1
28	1	0	1	1	0	0	1
29	1	1	0	1	0	0	1
30	1	1	1	0	0	0	1
31	0	0	1	1	1	0	1
32	0	1	0	1	1	0	1
33	0	1	1	0	1	0	1
34	1	0	1	1	1	0	1
35	1	1	0	1	1	0	1
36	1	1	1	0	1	0	1
37	0	0	1	1	0	1	1
38	0	1	0	1	0	1	1
39	0	1	1	0	0	1	1
40	1	0	1	1	0	1	1
41	1	1	0	1	0	1	1
42	1	1	1	0	0	1	1
43	0	0	1	1	1	1	1
44	0	1	0	1	1	1	1
45	0	1	1	0	1	1	1
46	1	0	1	1	1	1	1
47	1	1	0	1	1	1	1
48	1	1	1	0	1	1	1

obtained protocol when more than one are significant. The results of this chi-square analysis (Table 5a) show that for 32 of the 40 protocols only one theoretical protocol is significant. On the basis of the largest chi-square, 33 can be described as being classified primarily on the % Black dimension, 4 by Matrix Grain, 2 by Area, and 1 by Random. It should be noted that while this analysis shows no protocols as being classified by the Product of Inertia dimension, 3 were significantly described by that dimension, but not as well as by others; this reflects in the significant Subject x Product of Inertia interaction shown above. Over Days, the protocols of seven subjects can be consistently classified by the % Black dimension and one, by Matrix Grain. The significant Subject x Session interaction ($p<0.001$) suggests that a subject can change the basis of his classification; this is supported by the two subjects who were not consistent in the use of a particular dimension. The fact that 8 protocols are described by more than one dimension can be used as further support of a subject's ability to change dimensions. Although it can be argued that such results may actually be reflecting the use of a classification rule other than those tested but correlated with them, inspection of these protocols in terms of the five sequences which composed a daily session tend to indicate that these subjects may be changing classification rules before the end of a session. The non-significant Session main effect indicates that the Subject x Session interaction comes

Tables 5a and 5b.

Results of Chi-Square Comparison of Theoretical Protocols with Obtained Daily Protocols in Terms of Significance Level and Chi-Square.

Legend: A $\chi2$ = 48.0 represents a perfect fit for the comparison.

$d_{\%B}$	Comparison based on the theoretical Protocol of the % Black dimension
d_I	Comparison based on the theoretical Protocol of the Second Moment of Inertia dimension
d_{PI}	Comparison based on the theoretical Protocol of the Product of Inertia dimension
d_{MG}	Comparison based on the theoretical Protocol of the Matrix Grain dimension
d_{A1}	Comparison based on the theoretical Protocol of the Area (1 in.sq. vs 2 in.sq. + 4 in.sq.) dimension
d_{A2}	Comparison based on the theoretical Protocol of the Area (2 in.sq. vs 1 in.sq. + 4 in.sq.) dimension
d_{A3}	Comparison based on the theoretical Protocol of the Area (4 in.sq. vs 1 in.sq. + 2 in.sq.) dimension

Table 5a.

EXPERIMENT I

	Session 1	Session 2	Sesion 3	Session 4
S_1	$d_{\%B}<.001$ $\chi^2=44.2$	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{A3}<.001$ $\chi^2=24.0$ $d_{A1}<.02$ $\chi^2=6.0$ $d_{A2}<.02$ $\chi2=6.0$	$d_{A1}<.001$ $\chi^2=48.0$
S_2	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=48.0$
S_3	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=44.2$	$d_{\%B}<.001$ $\chi^2=19.8$ $d_{A2}<.01$ $\chi^2=9.9$ $d_{A3}<,05$ $\chi^2=4.7$	$d_{\%B}<.001$ $\chi^2 24.00$ $d_{A2}<.05$ $\chi^2=4.6$
S_4	Random	$d_{\%B}<.01$ $\chi^2=8.1$ $d_{MG}<.05$ $\chi^2=4.1$	$d_{\%B}<.001$ $\chi^2=44.2$	$d_{\%B}<.001$ $\chi^2=44.2$
S_5	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=44.2$	$d_{\%B}<.001$ $\chi^2=48.0$
S_6	$d_{\%B}<.001$ $\chi^2=40.2$	$d_{\%B}<.001$ $\chi^2=40.6$	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=48.0$
S_7	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=48.0$
S_8	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=48.0$
S_9	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=44.2$	$d_{\%B}<.001$ $\chi^2=40.2$	$d_{\%B}<.001$ $\chi^2=44.2$
S_{10}	$d_{MG}<.001$ $\chi^2=27.0$	$d_{MG}<.001$ $\chi^2=19.0$ $d_{PI}<.05$ $\chi^2=4.1$	$d_{MG}<.001$ $\chi^2=27.2$ $d_{PI}<.05$ $\chi^2=5.4$	$d_{MG}<.001$ $\chi^2=21.9$ $d_{PI}<.02$ $\chi^2=5.5$

Table 5b.

EXPERIMENT II

	Session 1	Session 2	Session 3	Session 4
S_1	$d_{\%B}<.02$ $\chi^2=5.5$	$d_{MG}<.05$ $\chi^2=5.4$	$d_{PI}<.05$ $\chi^2=4.2$ $d_{MG}<.05$ $\chi^2=4.2$	$d_{MG}<.02$ $\chi^2=5.96$
S_2	$d_I<.001$ $\chi^2=34.3$	$d_I<.001$ $\chi^2=21.8$	$d_I<.001$ $\chi^2=19.8$	$d_I<.001$ $\chi^2=29.5$
S_3	$d_{\%B}<.001$ $\chi^2=44.2$	$d_{\%B}<.001$ $\chi^2=37.3$	$d_{\%B}<.001$ $\chi^2=37.3$	$d_{\%B}<.001$ $\chi^2=40.6$
S_4	$d_{PI}<.001$ $\chi^2=48.0$	$d_{PI}<.001$ $\chi^2=48.0$	$d_{PI}<.001$ $\chi^2=48.0$	$d_{PI}<.001$ $\chi^2=48.0$
S_5	$d_{A1}<.001$ $\chi^2=48.0$	$d_{A1}<.001$ $\chi^2=48.0$	$d_{A1}<.001$ $\chi^2=48.0$	$d_{A1}<.001$ $\chi^2=48.0$
S_6	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=48.0$	$d_{PI}<.001$ $\chi^2=48.0$	$d_{\%B}<.01$ $\chi^2=10.2$ $d_I<.01$ $\chi^2=6.9$
S_7	$d_{PI}<.02$ $\chi^2=5.9$ $d_{MG}<.02$ $\chi^2=5.9$	$d_{MG}<.001$ $\chi^2=18.4$ $d_{\%B}<.02$ $\chi^2=6.00$	$d_{MG}<.001$ $\chi^2=14.3$ $d_{\%B}<.01$ $\chi^2=9.6$	$d_I<.05$ $\chi^2=5.40$ $d_{A1}<.05$ $\chi^2=4.9$
S_8	$d_{\%B}<.001$ $\chi^2=30.1$	$d_I<.001$ $\chi^2=18.8$ $d_{\%B}<.01$ $\chi^2=6.7$	$d_I<.001$ $\chi^2=12.80$ $d_{\%B}<.01$ $\chi^2=8.90$	$d_I<.001$ $\chi^2=12.80$ $d_{\%B}<.01$ $\chi^2=8.9$
S_9	$d_{\%B}<.001$ $\chi^2=38.4$	$d_{PI}<.01$ $\chi^2=9.60$ $d_{\%B}<.05$ $\chi^2=5.40$	$d_{\%B}<.01$ $\chi^2=9.60$ $d_{MG}<.01$ $\chi^2=8.90$	$d_{\%B}<.01$ $\chi^2=10.2$
S_{10}	$d_{A1}<.001$ $\chi^2=48.0$	$d_{\%B}<.001$ $\chi^2=48.0$	Random	$d_{\%B}<.001$ $\chi^2=14.52$ $d_{A1}<.01$ $\chi^2=8.4$

about through subject change and not as a result of any change in the experiment itself.

The significant Subject x Dimension x Sessions interaction ($p<,001$) indicates that changes in processing occur through subjects changing the dimensional basis of their classification over time; furthermore, this interaction strongly supports previous conclusions regarding Subjects, Sessions, and Dimensions.

The non-significant Dimensions x Sessions interaction implies that there was no consistency in the selection of dimensions over sessions by the subjects. However, inspection of Table 5a, where only one subject changed his primary dimension over sessions, suggests that the number of shifts, on primary dimensions, that was made was so small that they could not be distinguished from error. This statement does not contradict the very significant Subject x Dimension X Session interaction. Inspection of Table 5a also shows that several dimensions could be significant on any one day for an individual subject. (The subjects possibly shifting dimensions within a session). However, only one change in primary dimensions occurred over sessions when the primary dimension, in terms of the Phi-Coefficient, was determined.

Appendix B presents the classification protocols for first trial data for each pattern as obtained on the first experimental session with the order rearranged to conform to that given in Appendix A. As can be seen the protocol for most subjects is very orderly and systematic and compares favorably to the theoretical protocols. Runs tests performed on this data (Table 6) show that eight out of the ten subject protocols in Exp. I were not random. This suggests that before the end of the first sequence, i.e., without having seen all the stimuli at least once, most subjects have generated a decision rule, or hypothesis, concerning classification of the patterns and apply it to all of the stimuli.

Experiment II

Exp. II is a replication of Exp. I. Ten different subjects were used, and the patterns were rotated ninety degrees counter clockwise from the position seen in Exp. I.

The results of the analysis of variance substantiate those of Exp. I and are presented in Table 7. The nonsignificant effect of patterns again suggests the generalizability of the findings to the stimulus domain of these patterns. The results confirm that individual differences (Subjects, $p<0.001$) affect the processing of patterns and that the % Black dimension is descriptive of the underlying basis for the average classification process ($p<0.05$). Although the effect is not as strong as in Exp. I, no other dimension was found capable of describing average classificatory behavior. The significant interaction effects of Subject x % Black, Subject x Area, Subject x Inertia, Subject x Product of Inertia, and Subject x Matrix Grain beyond the 0.001 level, and of the Subject x Random at the 0.01 level indicate that all of these dimensions can be used as a basis for classify-

Table 6

Runs Test Data for the First Sequence of Presentation as Seen in Appendix B

		No. of Runs	Z Score	P (one-tailed)
Experiment I	S1	31	3.561	.00023
	S2	24	5.1188	.00003
	S3	22	5.538	.00003
	S4	47	0.413	(.3409)
	S5	27	4.514	.00003
	S6	32	3.257	.0007
	S7	24	5.128	.00003
	S8	22	5.538	.00003
	S9	28	4.249	.00003
	S10	48	0.514	(.3050)
Experiment II	S1	51	0.722	(.2358)
	S2	24	4.625	.00003
	S3	32	3.444	.0003
	S4	40	1.759	.0392
	S5	39	1.621	.0526
	S6	24	5.122	.00003
	S7	32	3.201	.0007
	S8	45	0.805	(.2090)
	S9	34	2.348	.0094
	S10	39	1.328	(.0901)

Table 7

Results of Analyses of Variances for Experiment II

Factors	SS	df	MS	F or F"	P
Subject	20.77	9	2.31	22.50 (9, 432)	p<.001
Dimension	86.07	47			
% Black	55.54	1	55.54	* 6.76 (1, 9)	p<.05
Area	6.13	2	3.06	* 0.70 (2, 18)	
Inertia	5.75	1	5.75	* 1.16 (1, 9)	
Pr. of I	12.81	1	12.81	* 1.55 (1, 9)	
Matrix	0.89	1	0.89	* 2.00 (1, 9)	
Random	4.96	41	0.12	* 0.93 (41, 378)	
Patterns	5.18	48	0.11	1.05 (48, 432)	
Sessions	2.83	3	0.94	* 1.01 (3, 34)	
S x D	323.41	423			
S x %B	73.07	9	8.19	79.15 (9, 432)	p<.001
S x Area	79.38	18	4.41	42.99 (18, 432)	p<.001
S x I	44.63	9	4.96	48.34 (9, 432)	p<.001
S x Pr I	74.05	9	8.23	8.02 (9, 432)	p<.001
S x MG	3.49	9	0.39	3.78 (9, 432)	p<.001
S x R	48.81	369	0.13	1.29 (369, 432)	p<.01
S x P	44.31	432	0.10		
S x Se	23.28	27	0.86	25.45 (27,1296)	p<.001
D x Se	14.43	141	0.10	1.16 (251, 1200)	p<.05
P x Se	3.90	144	0.02	0.80 (144, 1296)	
S x D x Se	115.20	1269	0.09	2.68 (1269,1296)	p<.001
S x P x Se	43,90	1296	0.03		

ing patterns. A difference from Exp. I should be noted in that the Subject x Inertia interaction is significant for Exp. II.

The significant Subject x Session interaction ($p<0.001$) again shows that subjects can shift the basis of their classification over the course of an experiment; the non-significance of the Session main effect again suggest that the change is due to subject change. The significant Subjects x Dimensions x Sessions interaction ($p<0.001$) indicates that shifts in classifications over time are made by subjects transferring to other dimensions. This very strong effect, as in Exp. I, gives further support to the previous conclusions. In Exp. II the Dimension x Session interaction is significant at the 0.05 level; this is in contrast with the non-significant result for this effect in Exp. I. It would seem unlikely that two different processes are operating. From Tables 5a and 5b it appears that an insufficient number of shifts were made in Exp. I in contrast to the shifts made in Exp. II to permit significant differences from error. A significant Dimension x Session effect suggests that there may be a consistent pattern to the selection of dimensions which are used as the basis of classification by the subjects.

Using the procedure detailed in Exp. I the 40 obtained protocols were compared to the theoretical ones. The results of this analysis (Table 5b) show that for 27 protocols only one theoretical comparison is significant. On the basis of the largest chi-square 14 can be described as being classified primarily by the % Black dimension, 5 by Area, 8 by Inertia, 6 by Product of Inertia, 4 by Matrix Grain, 1 by Random, and 2 equally well by Product of Inertia or Matrix Grain. Four of the subjects were consistent in their use of a decision rule throughout the course of the experiment. The results of the runs tests (Table 6) performed on the first trial data of the first session show that five of the ten subjects were not random at a high level of significance and two were marginally significant. Again, this supports the position that most subjects have formed a classification rule before seeing all the patterns and apply it to those patterns.

The results from these two experiments are summarized:

1. There are individual differences in the classification of patterns by subjects.
2. Subjects can change their rules of classification over time.
3. The change in classification arises through subjects using a different dimensional basis of classification over time.
4. Although the evidence is equivocable when subjects shift dimensions whether they tend to shift to the same dimensions, it appears as if the shifts may be somewhat consistent.
5. The controlled physical dimension, % Black, is representative of both mean and modal classificatory systems.
6. The dimensions of % Black, Area, Inertia, Product of

Inertia, Matrix Grain, and Random can be used as the basis of classification for patterns. The combined 80 protocols show that 58.75% can be described by the % Black dimension, 8.75% by Area, 10% by Inertia, 8.75% by Product of Inertia, 11.25% by Matrix Grain, and 2.50% by Random.

7. 75% of all the subjects had formed the classification rule before seeing all the patterns at least once.

8. The results were found to be generalizable to the stimulus domain of the patterns used in the experiments.

DISCUSSION

The results of this experiment suggest that pattern classification may be a probabalistic process. Previous theories based upon invariant, deterministic processing of perceptual information have difficulty in explaining the occurrence of individual differences in processing except by attribution to error. The large and replicable effect of individual differences found in this study does not support such an interpretation. In reviewing contemporary theories of pattern processing, Neisser (1967) states that the data tends to support the view that pattern recognition involves a heirarchy of feature analysers but that it is doubtful that any theory which only involves parallel processing is adequate. Perhaps, the doubt has been added that previous theories which cannot account for individual differences are also inadequate. Stimulus sampling models for the processing of information extracted from brief visual displays of letters have recently been proposed (Rumelheart, 1968; Shaw, 1969); it would seem advantageous that such models be developed and modified for pattern stimuli.

From the subject protocol data, it appears that when told to classify patterns subjects form an hypothesis concerning the classification process. In this study 97.5% of these classification rules can be significantly described as being based on one of the five controlled physical dimensions. While the nature and mechanics of the processing system are beyond the scope of this study the nature of the data tends to offer some suggestions concerning them. In most cases the classification rule, or hypothesis, is formed before all patterns have been seen. This, in conjunction with the fact that the hypotheses were based on the controlled pattern dimensions, suggests that sampling of different features of the first several patterns provides enough information to enable construction of an hypothesis. Inspection of instances when a subject shifts his hypothesis from one dimensional basis to another may lead to understanding of the nature of the sampling process. Looking at these shifts at the coarse level of the Dimensions x Sessions interaction unfortunately leads to quivocation. The best that can be said is that there may be the development of a pattern according to which a subject chooses a dimension. Regardless of the sampling method, it appears that dimensions do not have equal probabilities of being sampled. If they did each dimension should have had a 20% chance of being used; the results (expressed in Point 6 of the Results Summary) tend to indicate otherwise.

Since the hypothesis appears to be formed before all the stimuli have been sampled, it seems necessary that the hypothesis must be fed back to previous stages of processing to assure that all future stimuli can be categorized by that hypothesis. Placing this supposition in a Perceptual Tuning-Response Bias context implies that perceptual tuning or attenuation may be influenced by the nature of the response. It remains for future work to test the validity of of this hypothesis.

The dimension of % Black has been found to be of prime importance in both experiments. While recognizing that this dimension was a fixed factor and that the results should be limited to the stimulus domain of patterns for this study, nonetheless the % Black dimension does appear to have implications for other areas in form perception.

In discussing the performance of monkeys on a simultaneous discrimination task involving matrix patterns, Polidora (1966) has suggested that a Unique Elements dimension (whether the same cell is in the same state in both matrices being compared) can describe the performance. Zusne (1967) has questioned this argument on both statistical and methodological grounds, to which Polidora (1967) has replied. The present study suggests that while Zusne is correct in challenging the validity of the Unique Elements dimension Polidora was in fact working with an important dimension of form. However, it may not be the Unique elements dimension, but the % Black dimension which appears to be confounded with Unique Elements, that was responsible for Polidora's results. It would be a simple matter to test Unique Elements against % Black as to their relative importance in form discrimination.

From post-experimental interviews with subjects, those who used the % Black dimension for classification tended to answer "Placed it in Group A if the pattern was white" or "placed it in Group A if it was a white shape on a black background and in Group B if the other way around" when asked to verbalize their classification criteria. This fact coupled with the significance of the % Black dimension suggests the possibility that in a pattern composed of two states, the subject establishes a point of subjective equality and that state which maps into a point below the PSE is responded to as figure and the complementary state necessarily mapping into a point above the PSE is responded to as ground. Reversibility, or a state of ambiguity, should arise when the two states map into points which approach the PSE; the nearer the states approach the PSE, the greater the ambiguity should be. Such a condition does appear to be in evidence for the Rock and Kremer study (1957). A pilot study (Catano, 1969), using procedures similar to the experiment reported here but a different set of matrix patterns, found that when subjects are asked to classify patterns having many different values of % Black into two groups, they use the median of the range of % Black values as a criterion. For example, if the set of patterns ranged from 10% to 40%, those patterns below 25% Black would be placed in one group, and those above, into the other. Many more errors of classification resulted for patterns whose % Black values were closer to the median than for those at the extremes of the range. It is generally stated that the principal mechanism of figure-ground is centrally located (Coren, 1969; Fisher, 1967). While the suggested relationship between a state of ambiguity and a PSE certainly is in agreement with this concept, it also tends to give greater emphasis to the peripheral stages, particularly how the scanning and coding of the two states affect their mapping into some subjective psychological space.

It is always hazardous to generalize from lower species to man, and even more so when going from the receptive field of a lower organism to the visual field of man. But in studies of receptive fields which suggested models based on lateral inhibition and excitation (Pickering and Varju, 1968; Henn and Grusser, 1968; Michael, 1968) the stimuli used involved two illumination states and forms such as circles or quadrilaterals which bear a surface resemblance to the stimuli used in this study. It is conceivable that the bias to select the % Black dimension as a basis of classification may be explained as a tendency of subjects to use that dimension which is processed first, the nature of the % Black dimension permitting processing at the retinal level.

The significance of the % Black dimension suggests that a large part of the results obtained in support of an Information Theory model of pattern perception (Garner, 1962) could be artifactual. If ambiguity does arise when both states of a two state pattern approach a PSE, and if the PSE is considered to be near the physical point of equality, then the number of such ambiguous patterns will increase with an increase in the number of cells in the matrix grid - - - an increase in total uncertainty. There is a greater probability of sampling an ambigous pattern from a set of patterns, the greater the total amount of uncertainty; e.g., for a 3 x 3 matrix, there is a probability of 0.506 of selecting a pattern with a % Black level of less than 33.3% or greater than 67.7%; for a 4 x 4 matrix, there is a 0.176 probability of selecting a pattern less than 31.2% or greater than 69.8%. Differences in performance which have been ascribed to differences in uncertainty may actually be due to processing different relative amounts of ambiguity.

Summary

A method has been proposed to determine the effect of individual differences on perceptual processing of patterns, while at the same time determining how well a sample set of patterns can be generalized to its stimulus domain.

The patterns were controlled on the physical dimensions of % Black, Area, Inertia, Product of Inertia, and Matrix Grain. % Black was found to be descriptive of average classificatory behavior, but all of the controlled dimensions were used as a basis of classification. It was found that subjects shifted dimensions over time; although the evidence is not conclusive, it appears that when shifts are made, they may be made in a somewhat consistent manner. The results strongly indicate that most subjects formed a classification rule before seeing all the patterns at least once.

An hypothesis-feedback model has been proposed as a mechanism for describing the results of the study.

The implications of the primary of the % Black dimension has been suggested for related areas such as simultaneous discrimination tasks, reversible figures, possible physiolog-

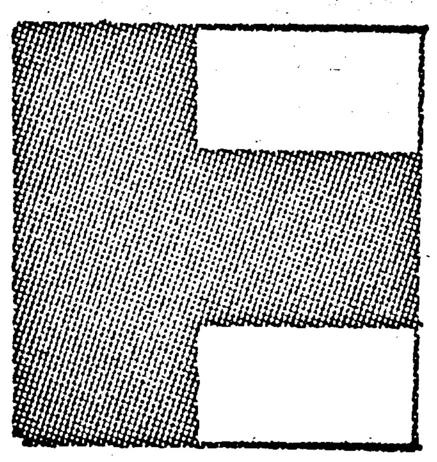
ical basis, and information theory approaches to pattern perception.

Appendix A

Each factorial combination is represented by a five digit combination where the first represents % Black; the second, Moment of Inertia; the third, Product of Inertia; the fourth, Matrix Grain; and the fifth, Area. Assigning the following digits to each of the dimensional values generates the code. Each of the patterns in Appendix A is titled with its descriptive code.

High % Black = 0	$(P_{xy} = 0) = 0$	$A_{1x} = 0$	$I_{lo} = 0$	$MG_{4x4} = 0$
Low % Black = 1	$(P_{xy} \neq 0) = 1$	$A_{2x} = 1$	$I_{hi} = 1$	$MG_{6x6} = 1$
		$A_{3x} = 2$		

1. 00000
2. 00001
3. 00002
4. 10000
5. 10001
6. 10002
7. 01000
8. 01001
9. 01002
10. 11000
11. 11001
12. 11002
13. 00100
14. 00101
15. 00102
16. 10100
17. 10101
18. 10102
19. 01100
20. 01101
21. 01102
22. 11100
23. 11101
24. 11102
25. 00010
26. 00011
27. 00012
28. 10010
29. 10011
30. 10012
31. 01010
32. 01011
33. 01012
34. 11010
35. 11011
36. 11012
37. 00110
38. 00111
39. 00112
40. 10110
41. 10111
42. 10112
43. 01110
44. 01111
45. 01112
46. 11110
47. 11111
48. 11112



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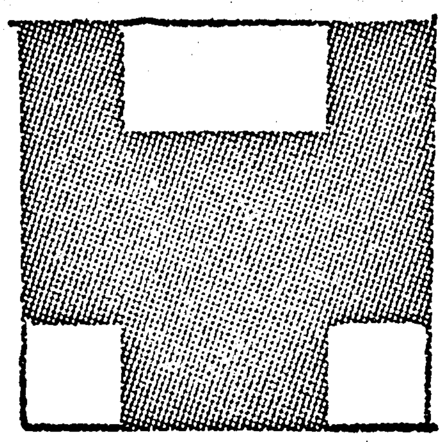

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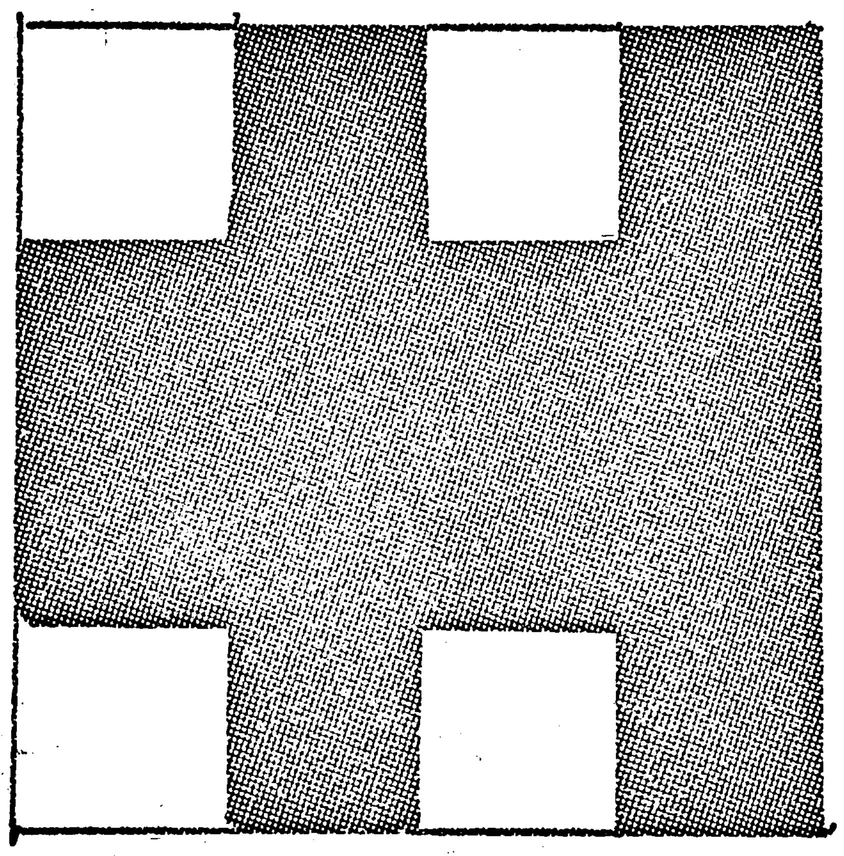

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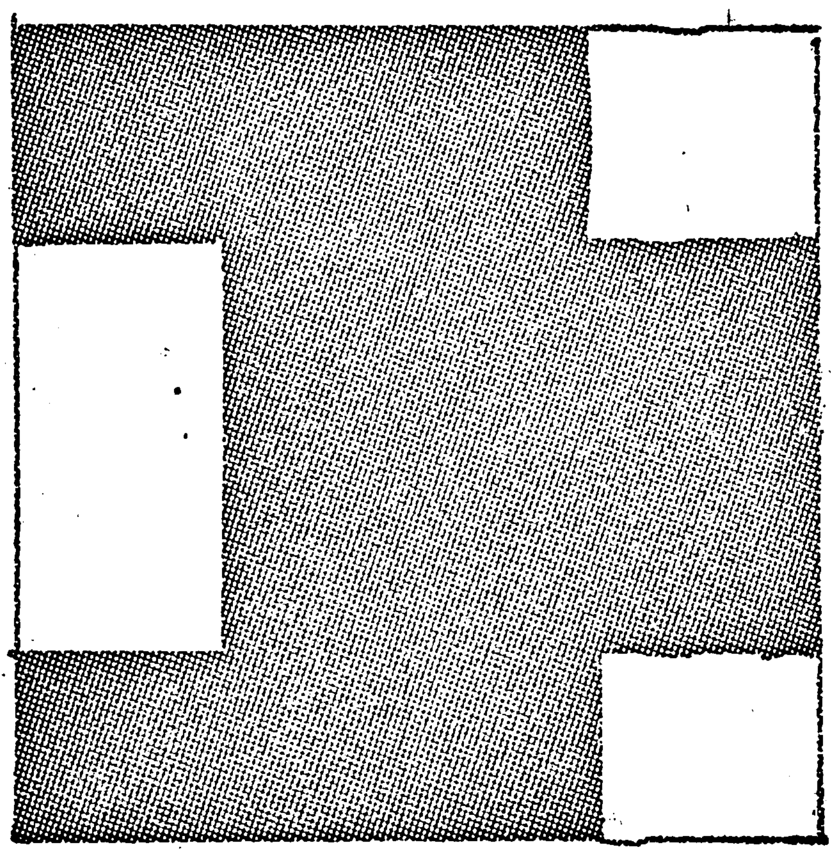

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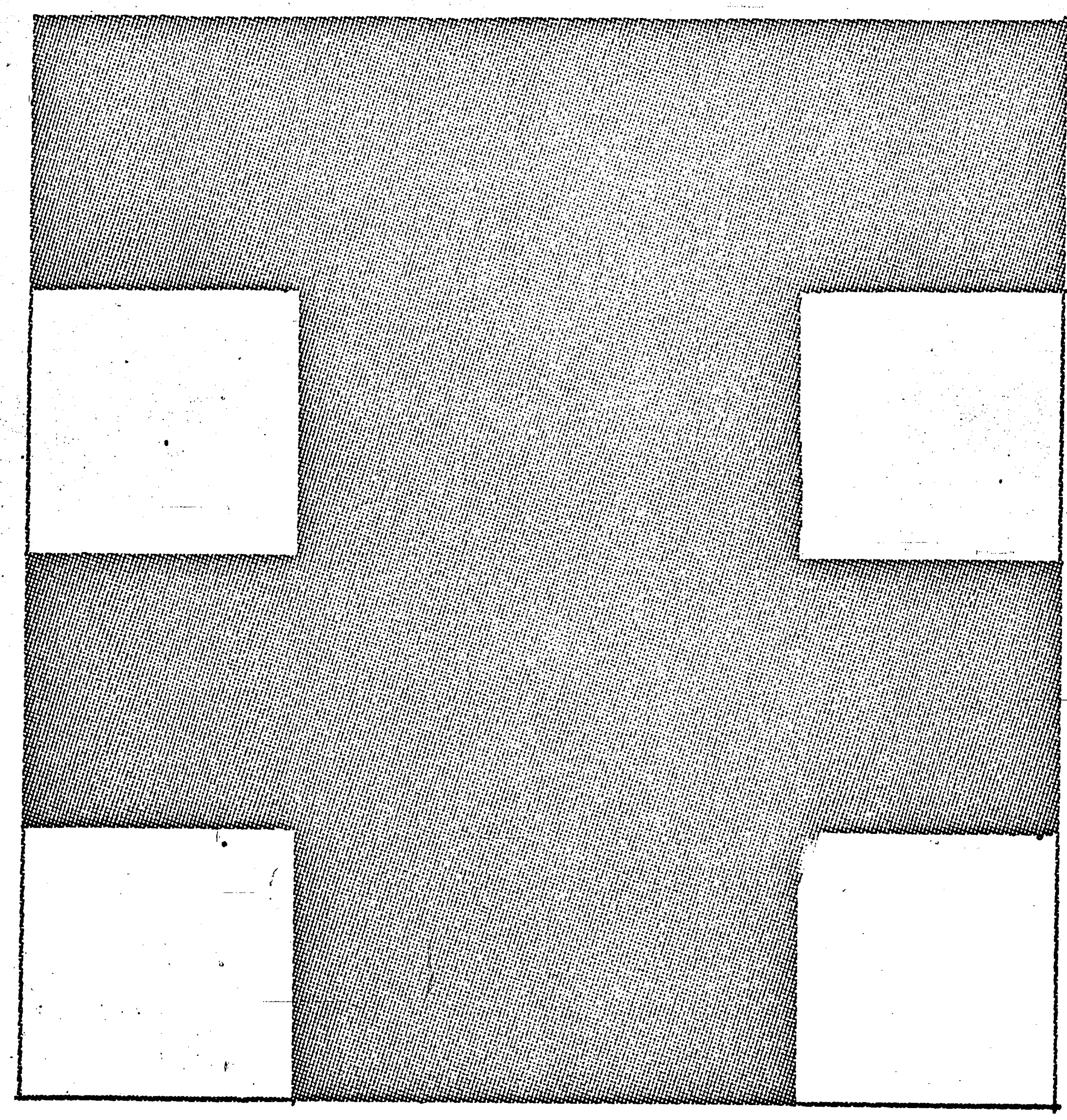

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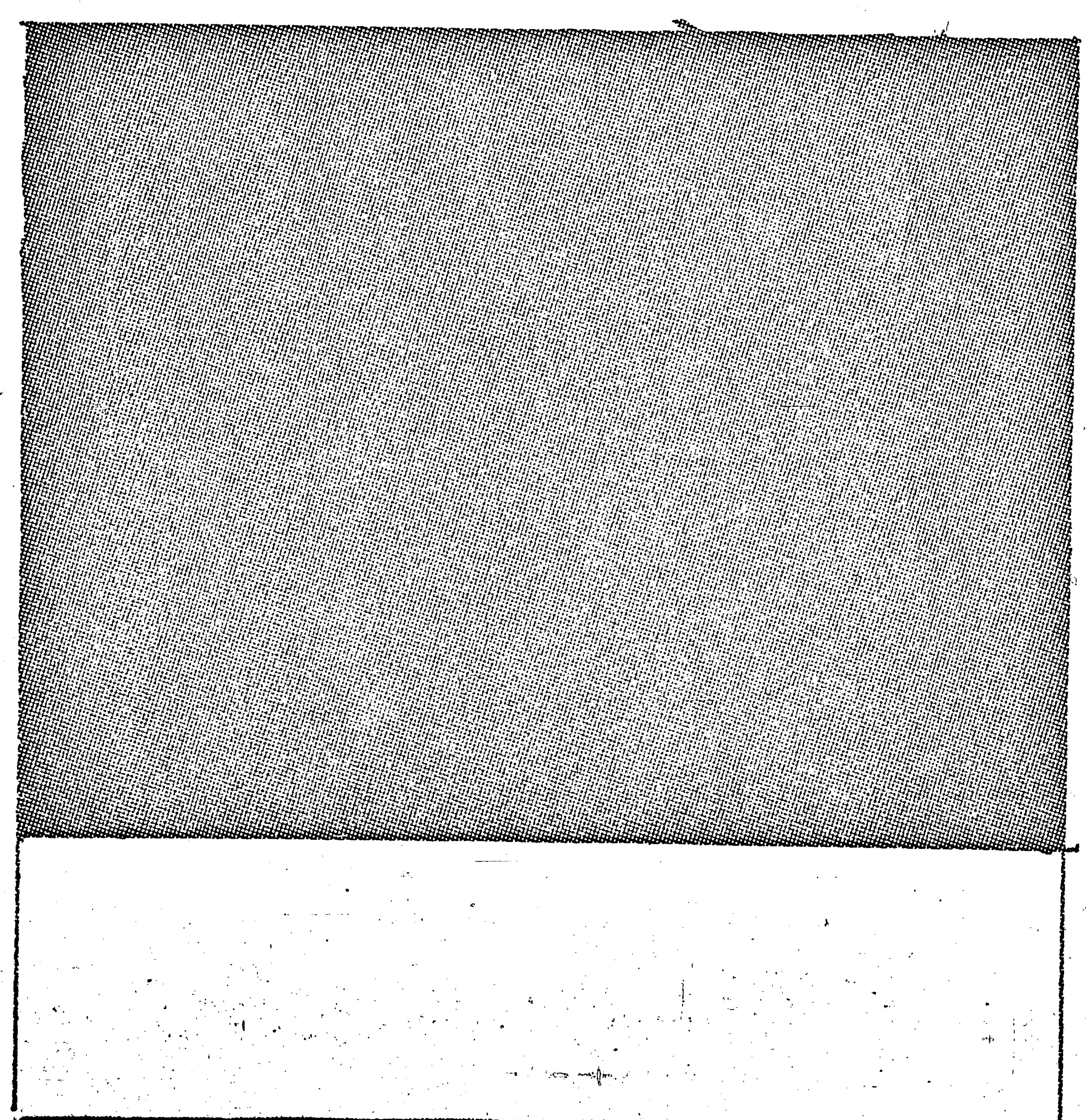

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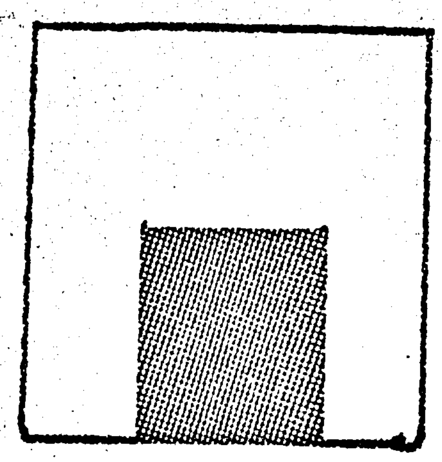

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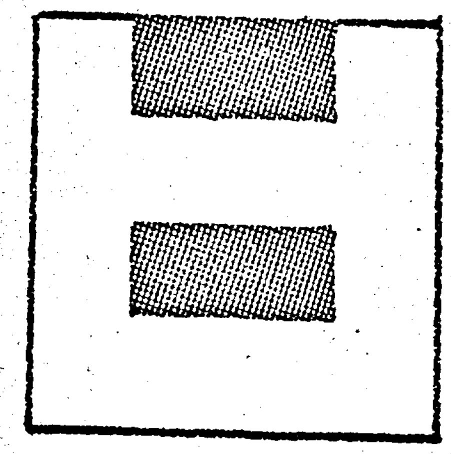

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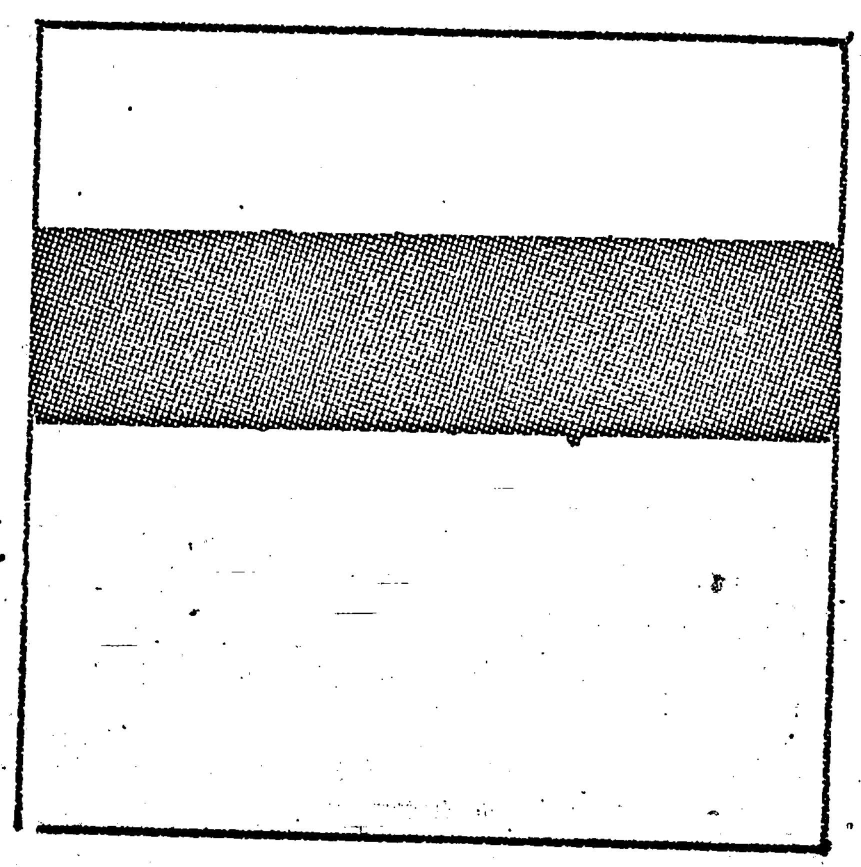

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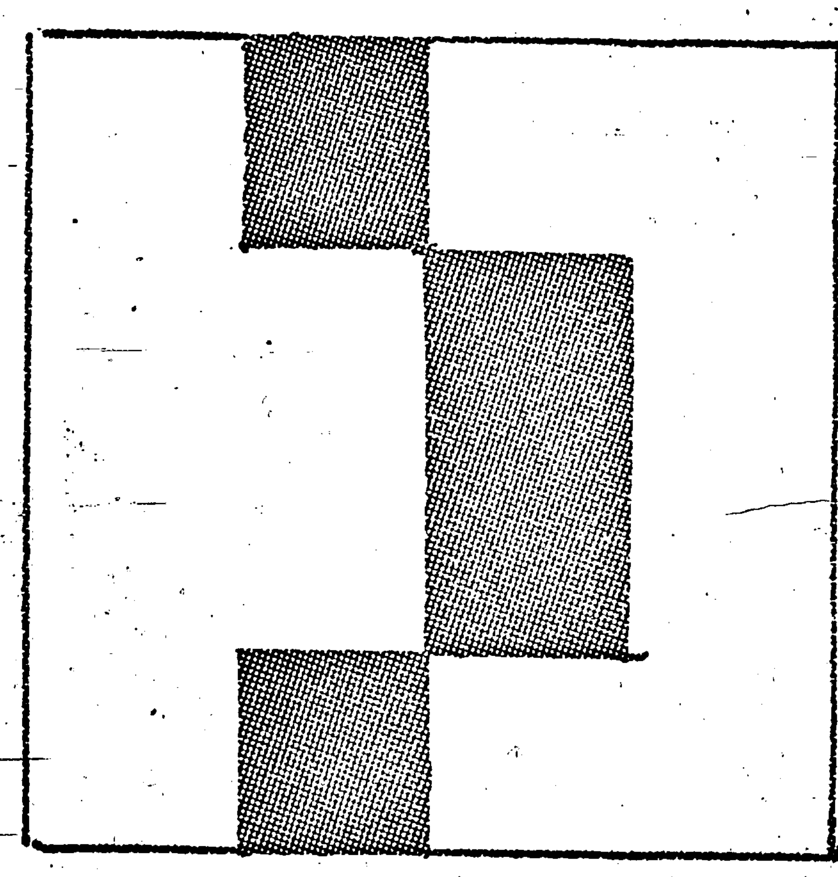

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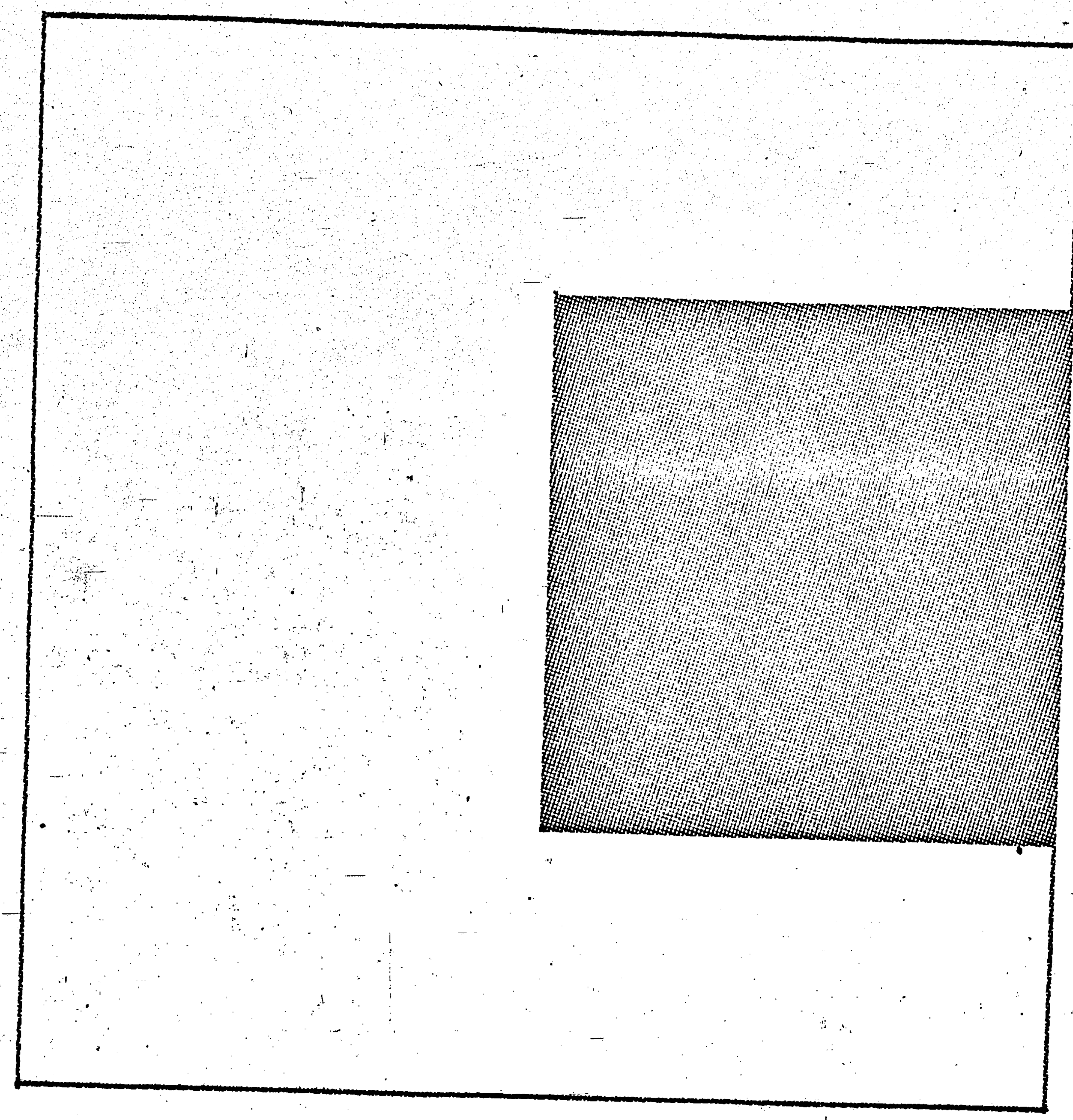

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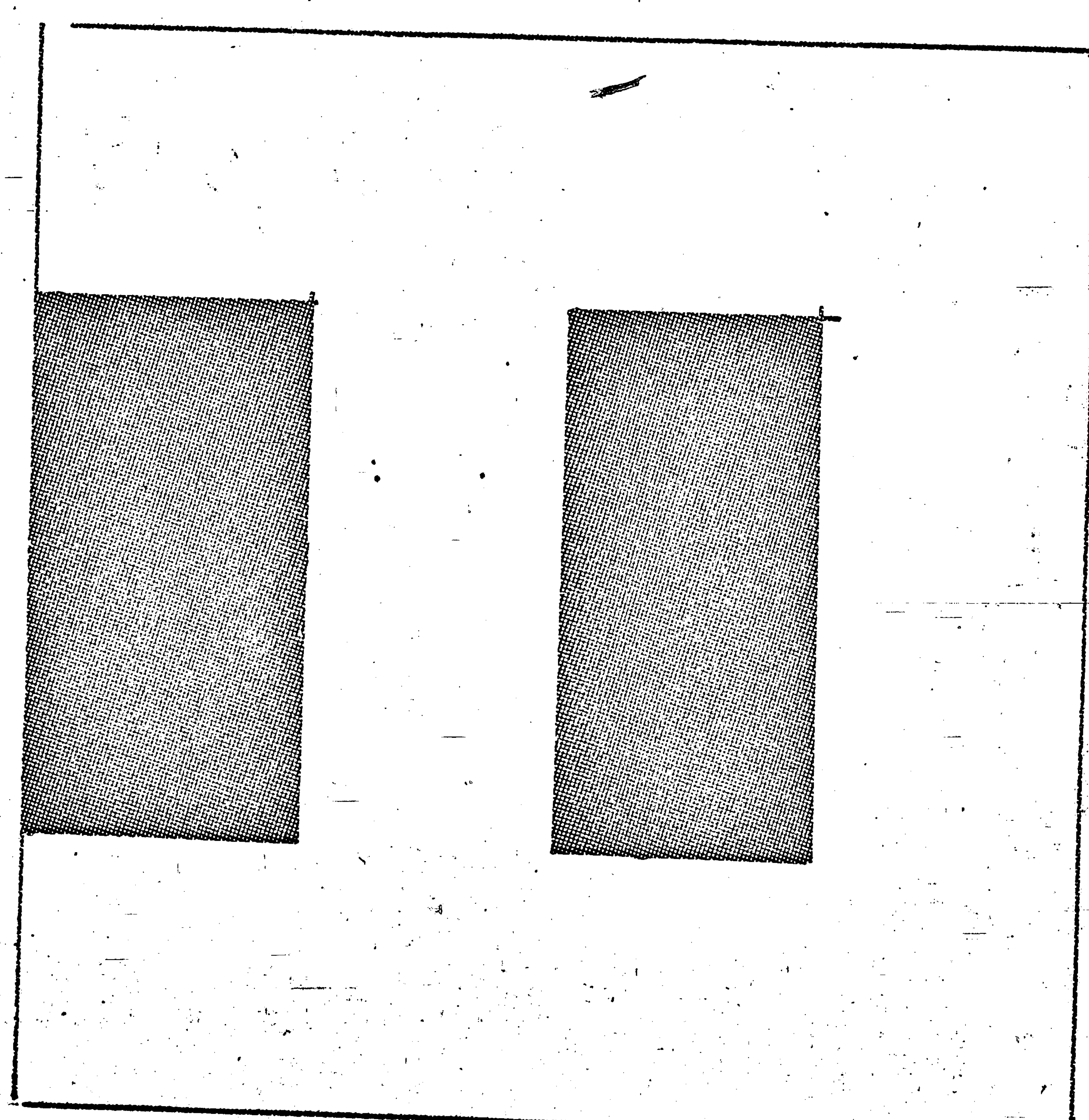

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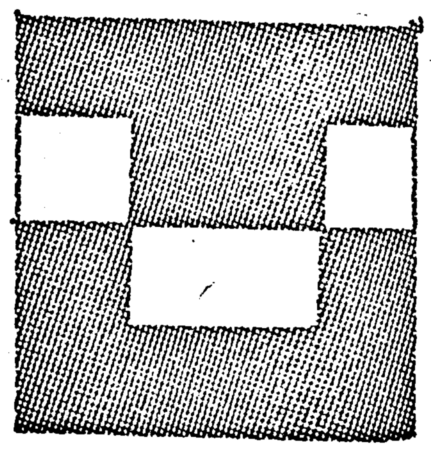

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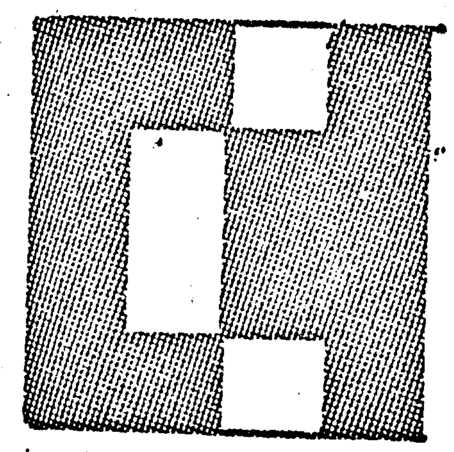

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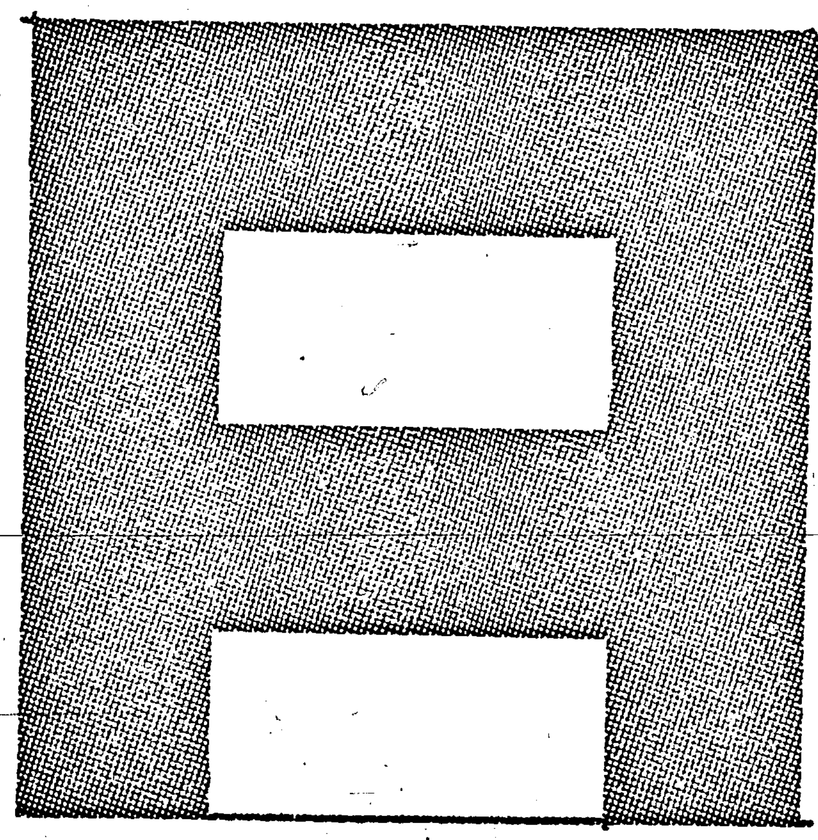

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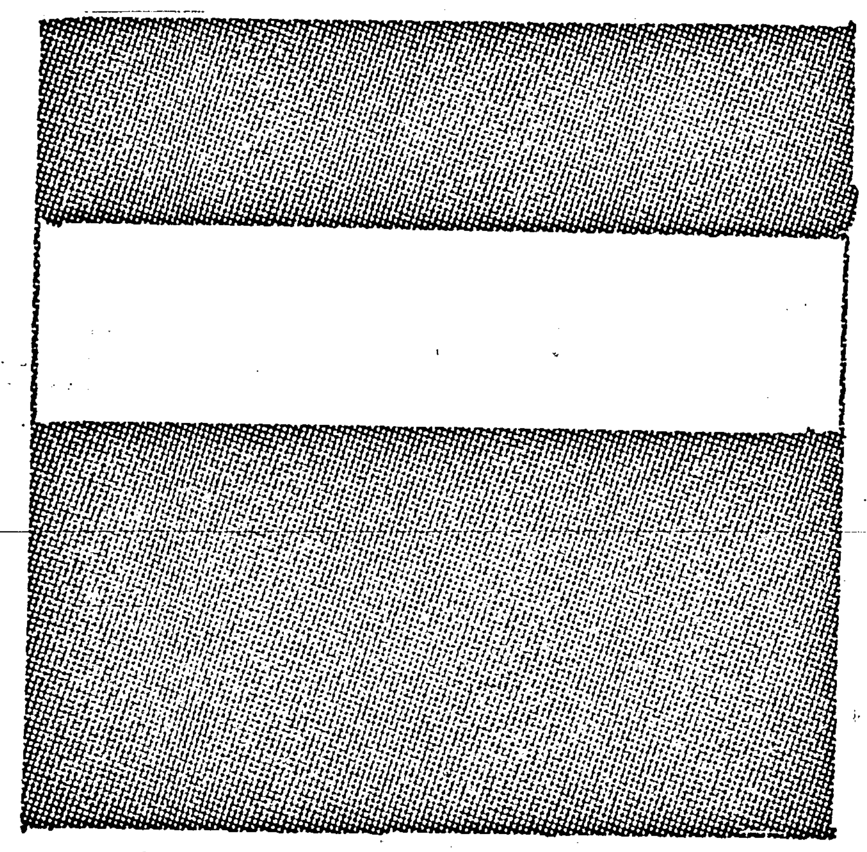

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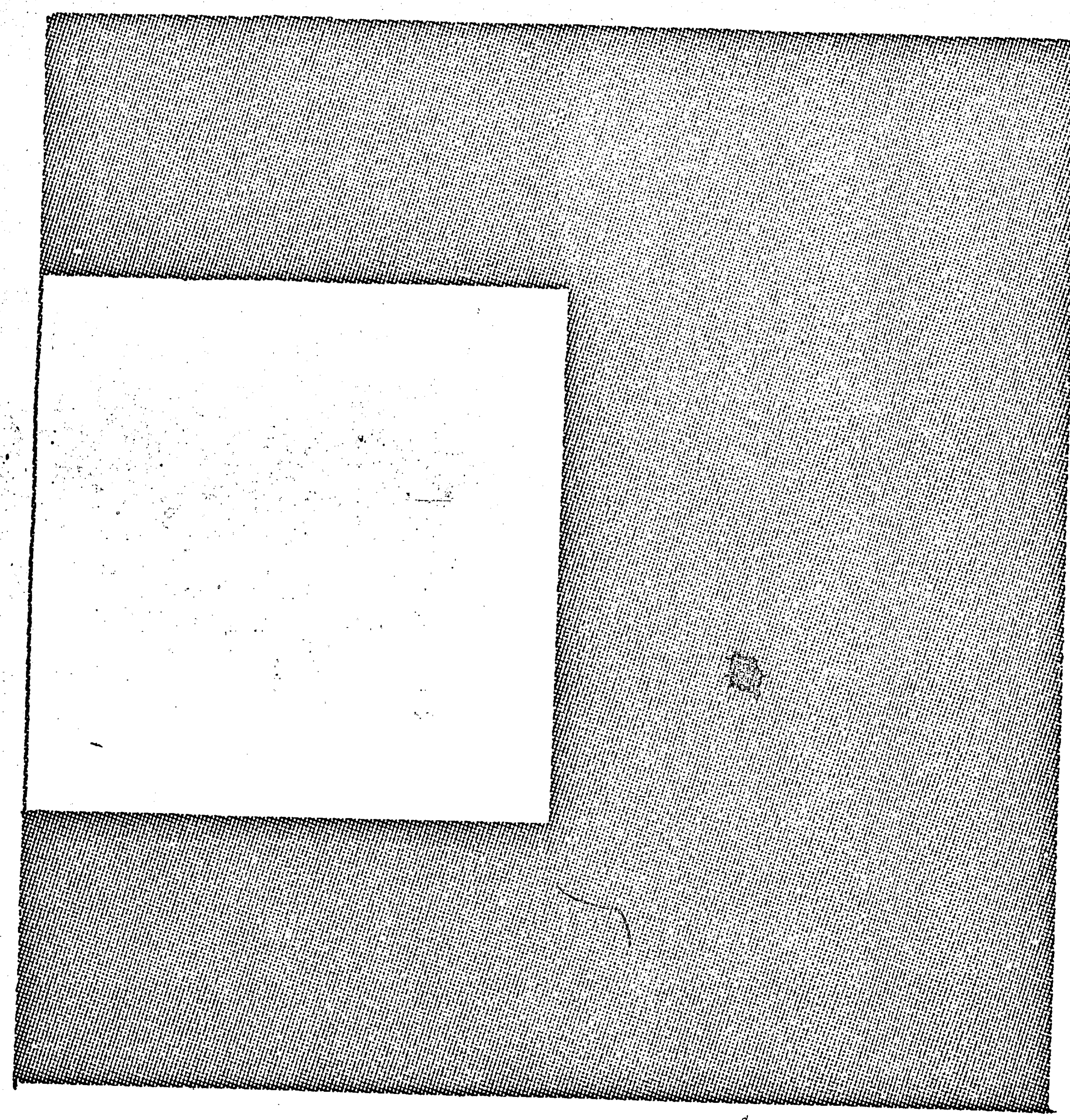

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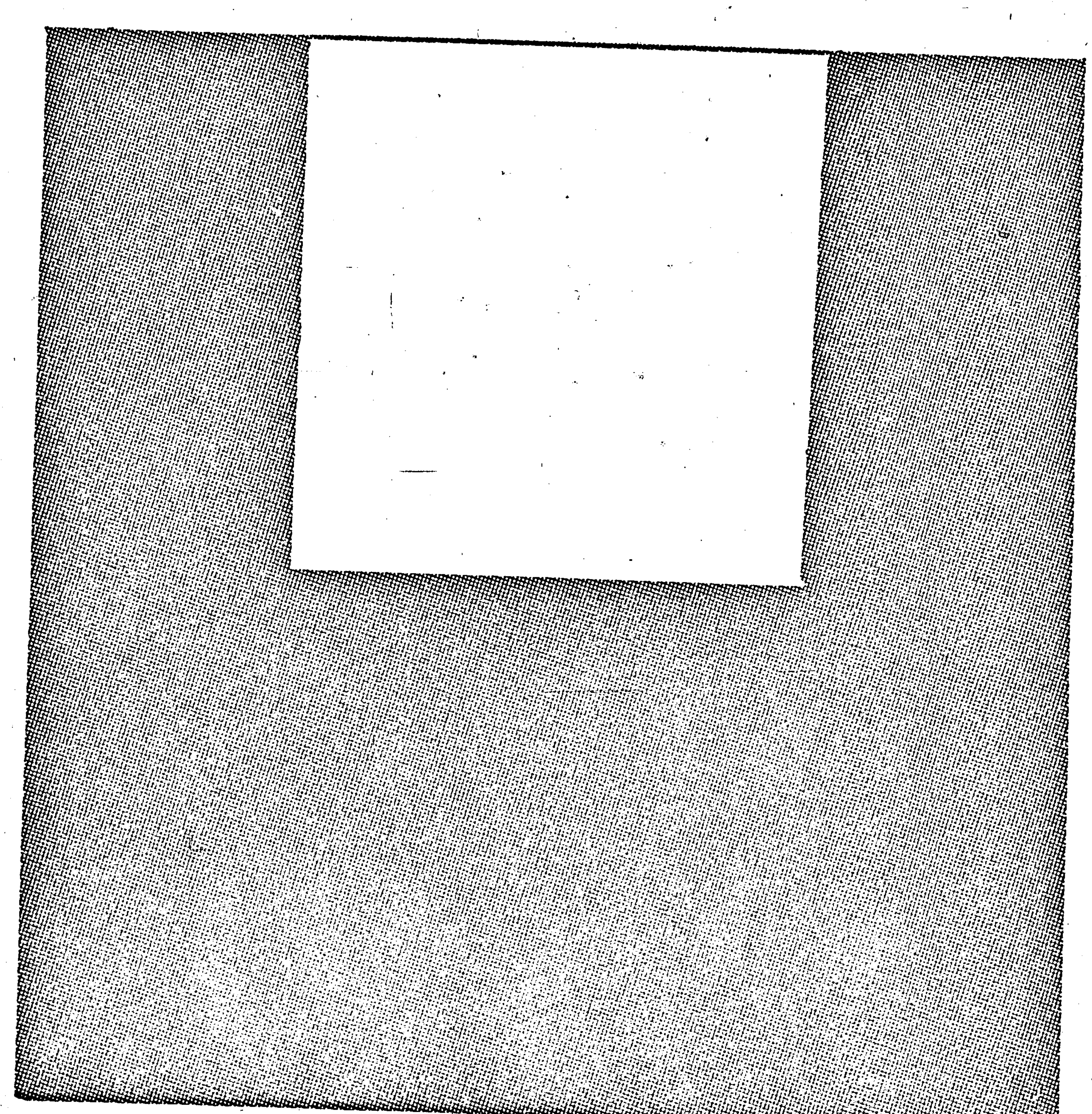

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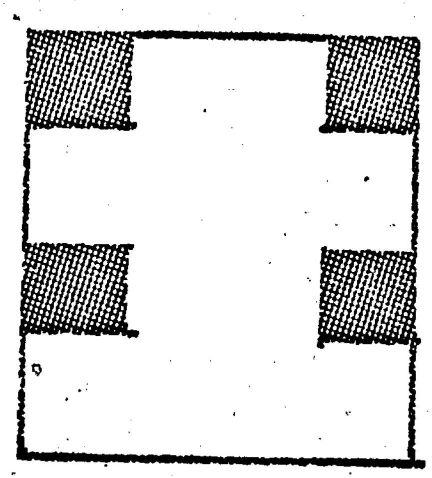

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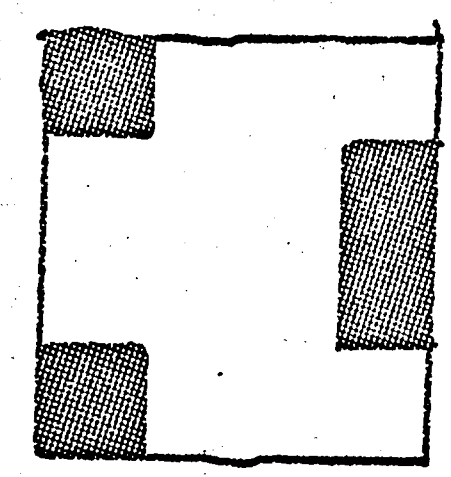

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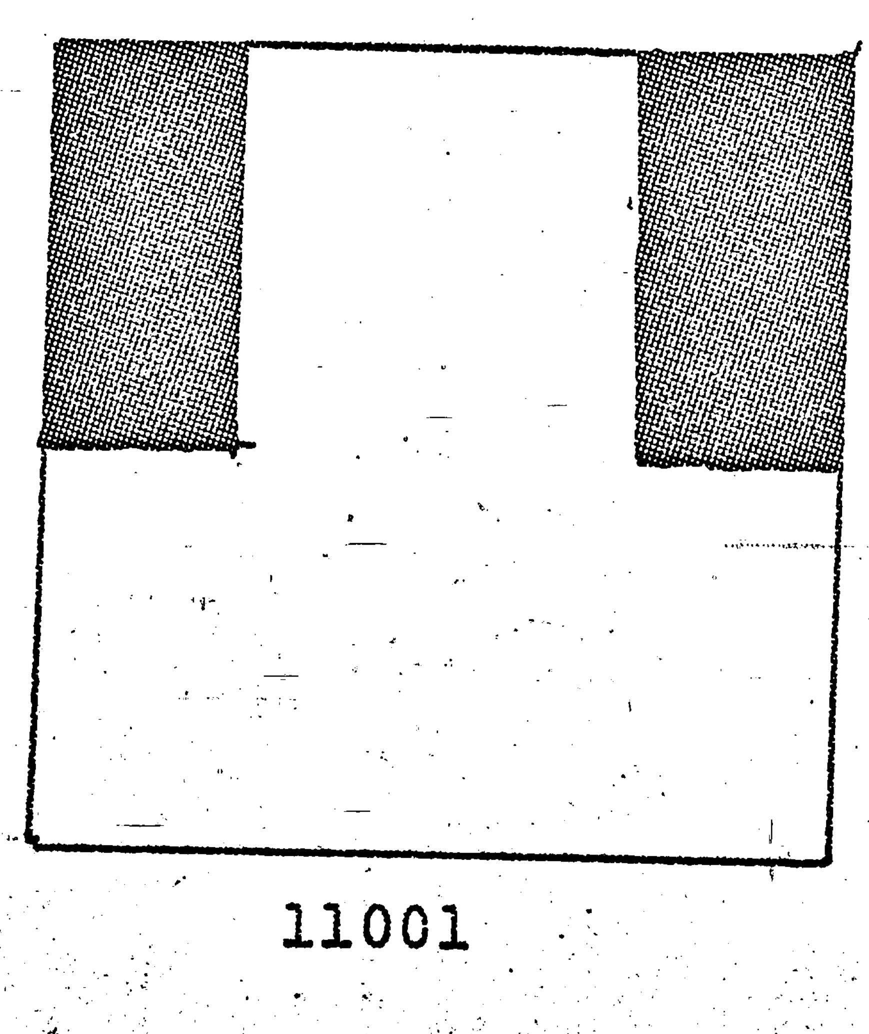

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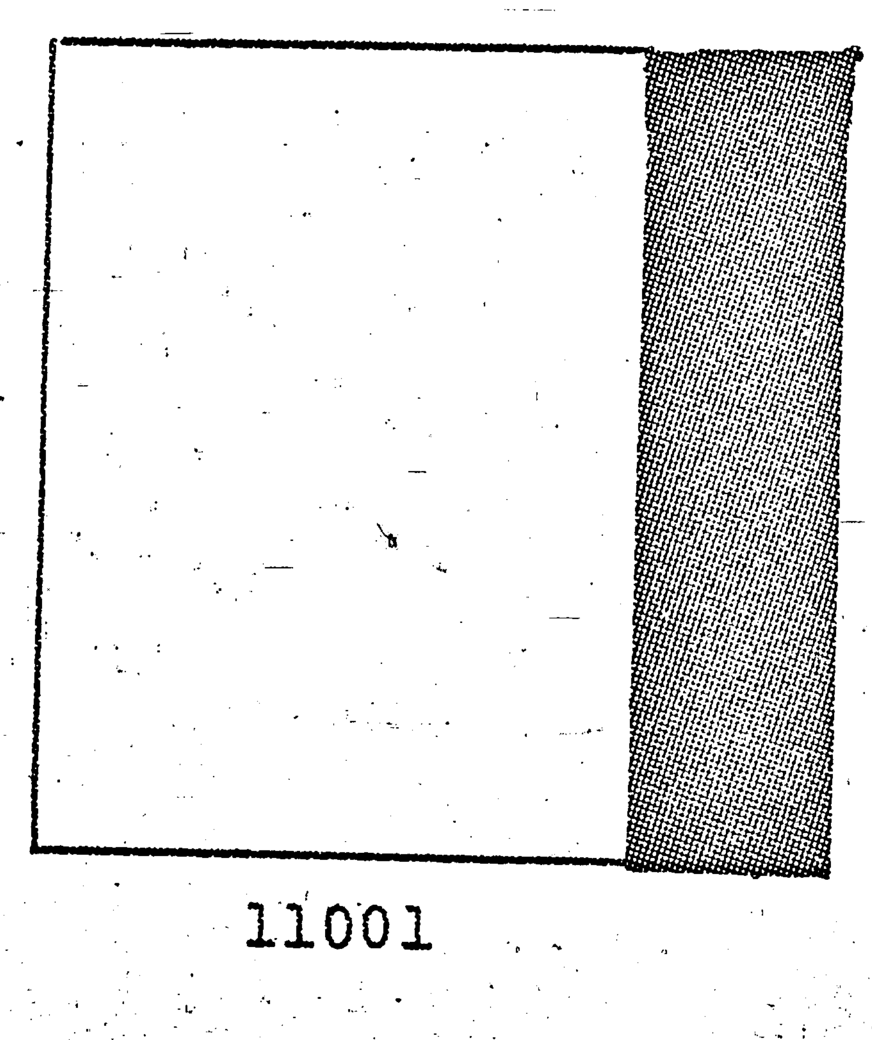

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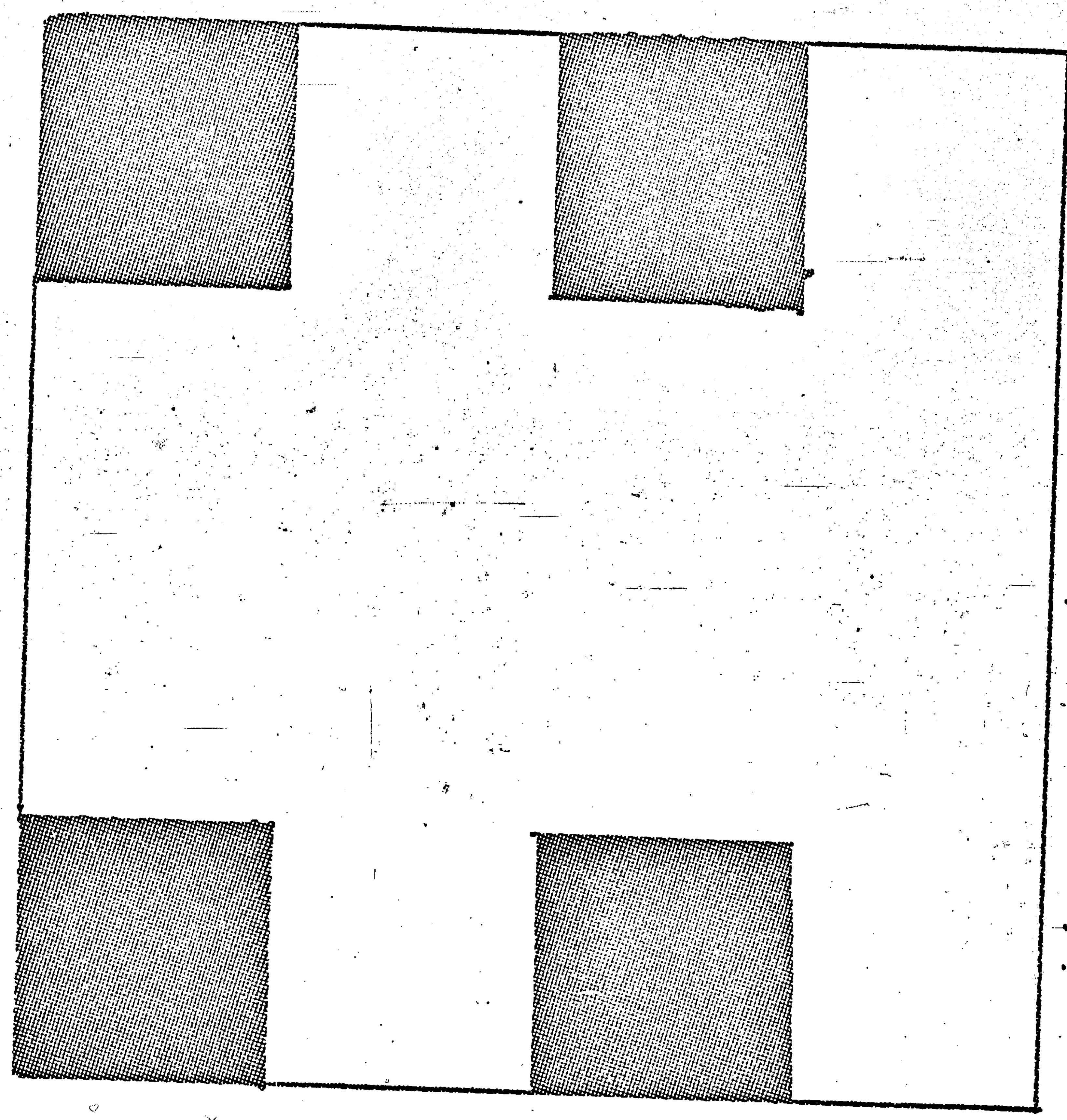

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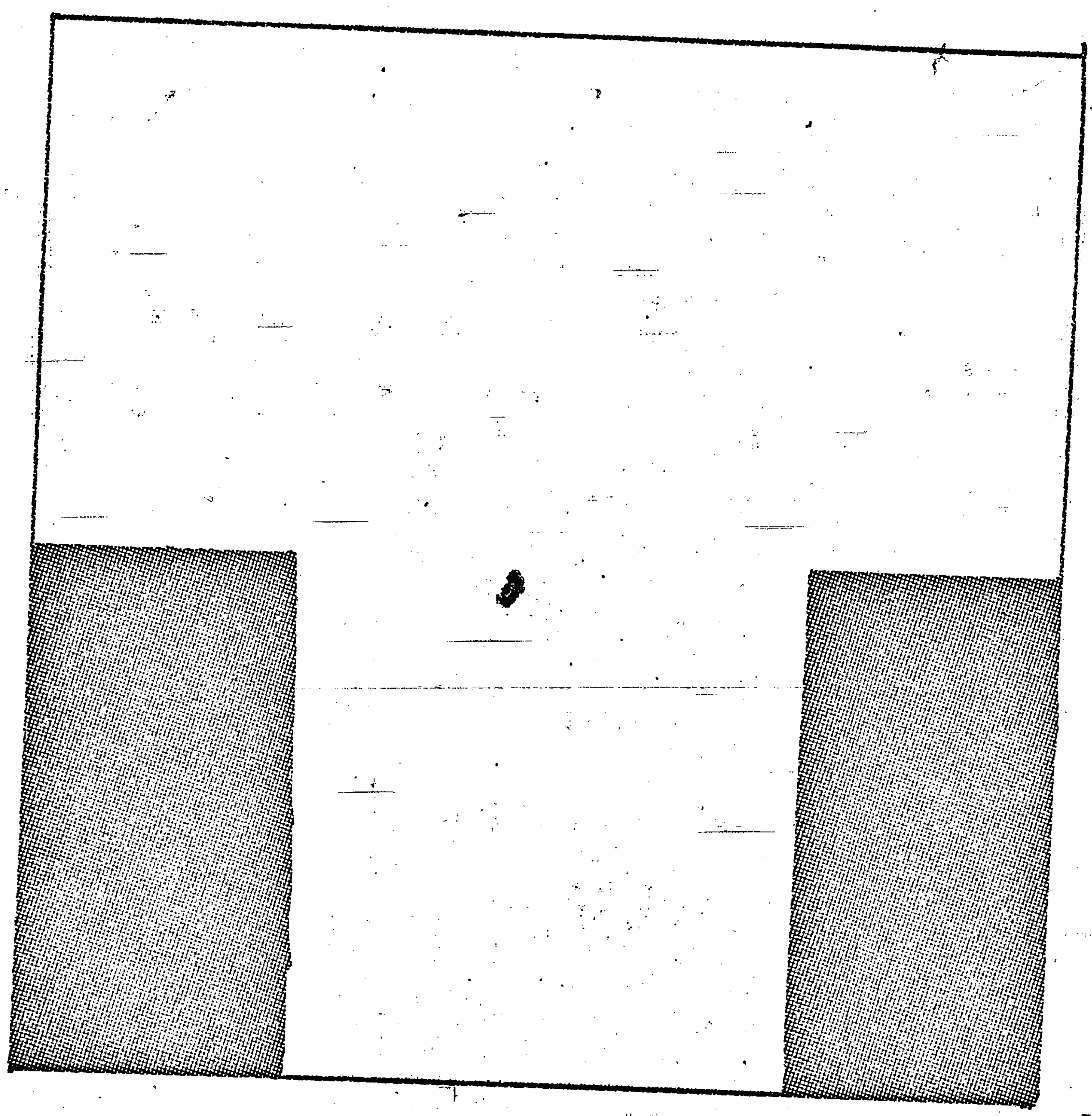

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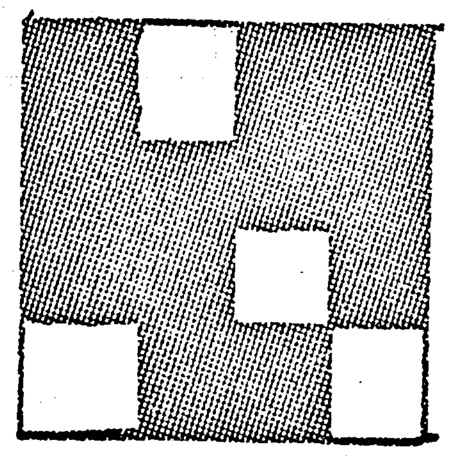

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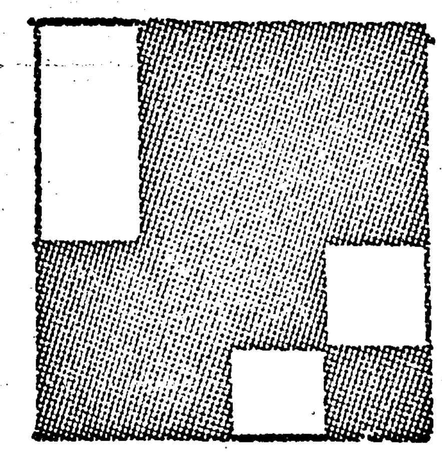

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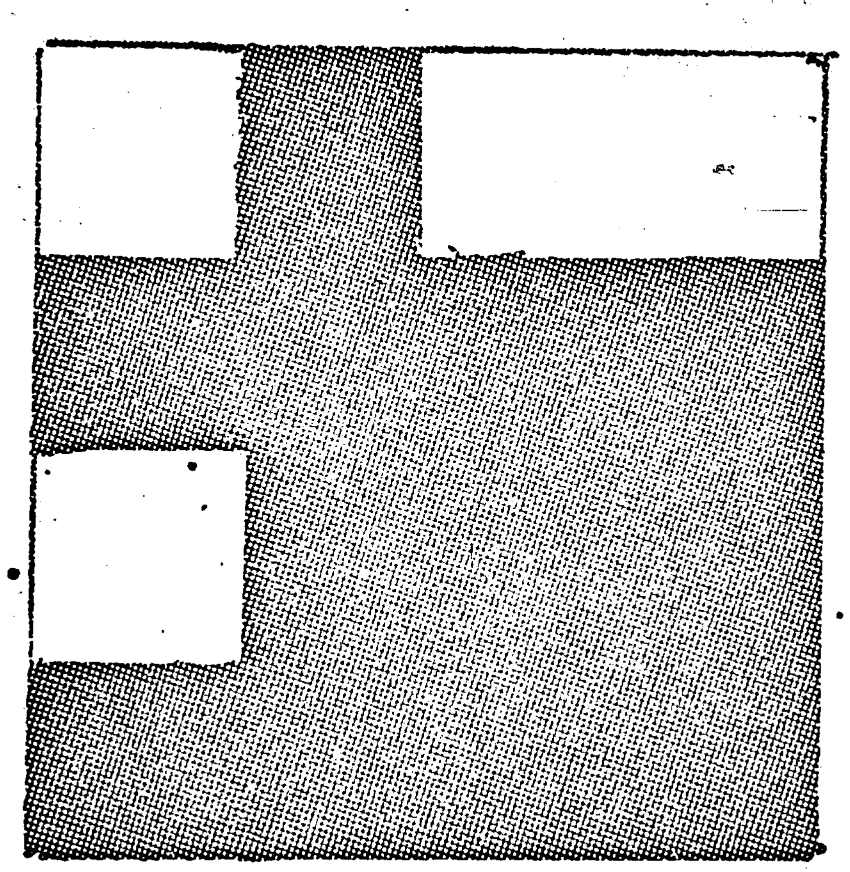

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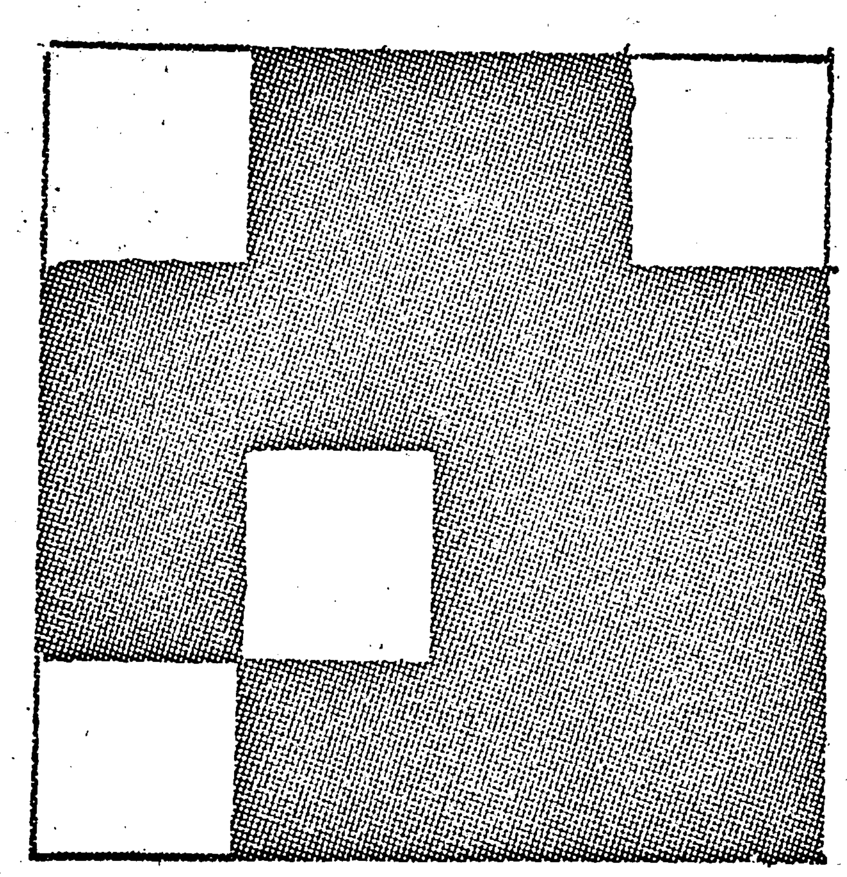

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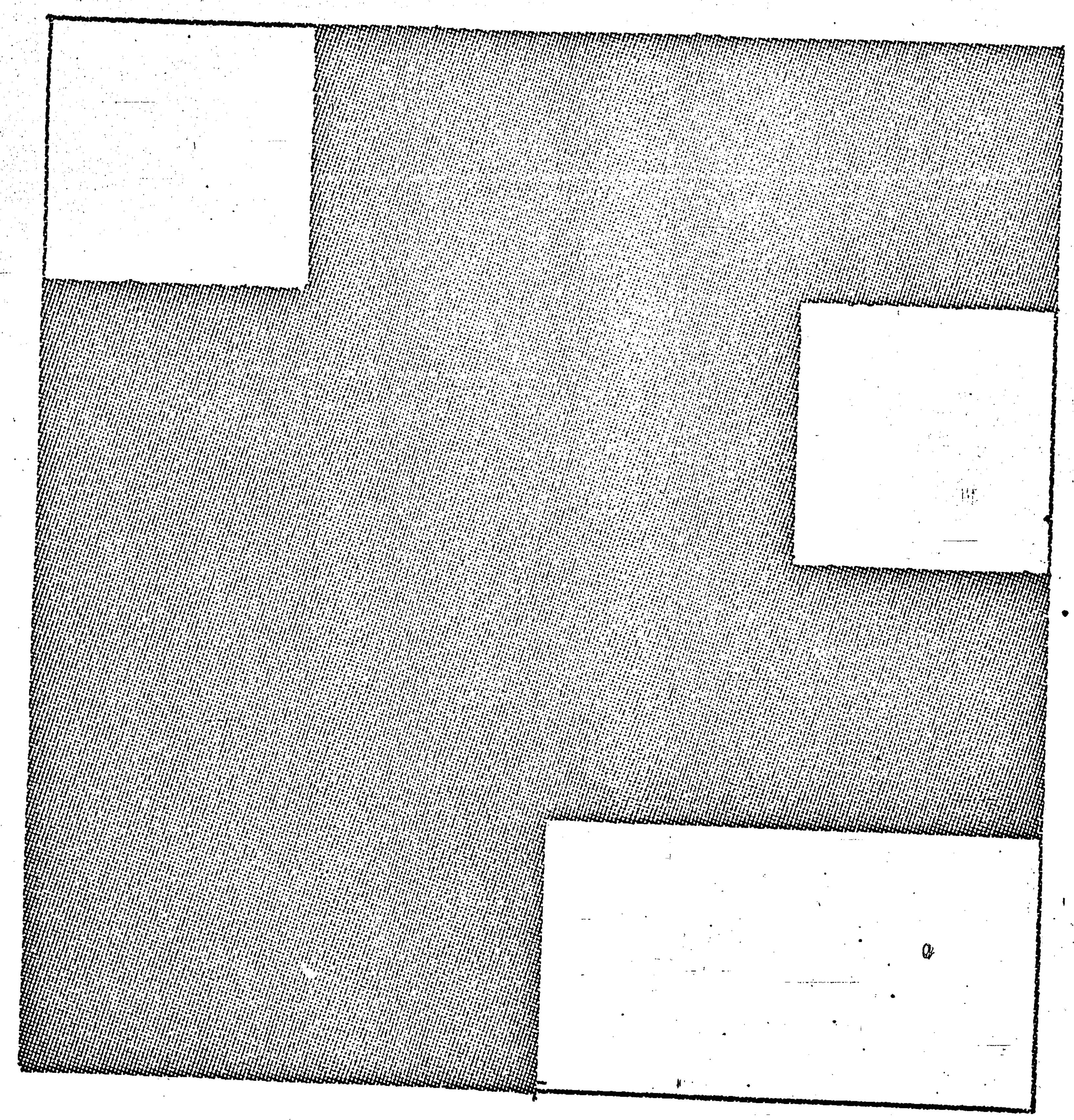

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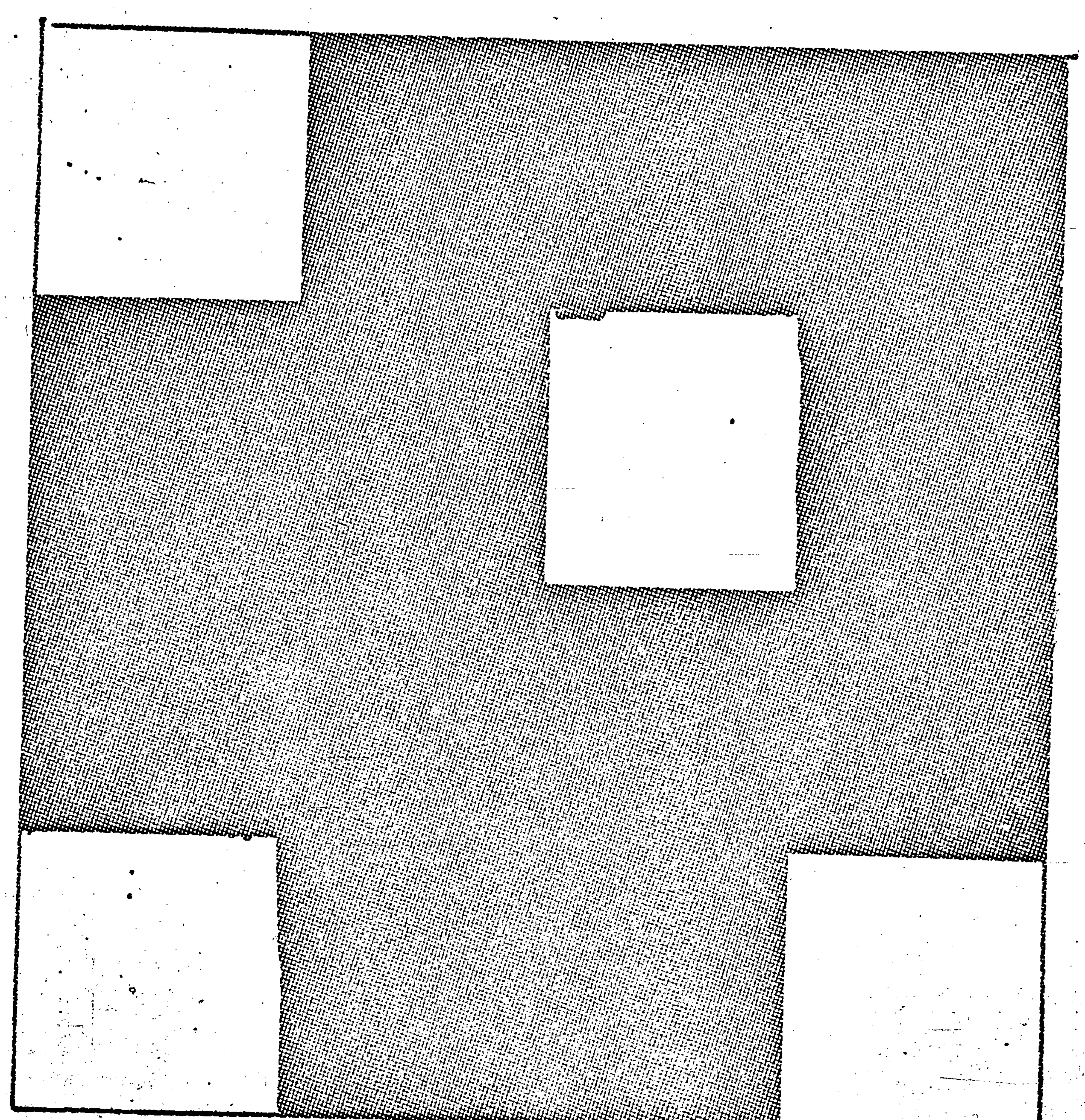

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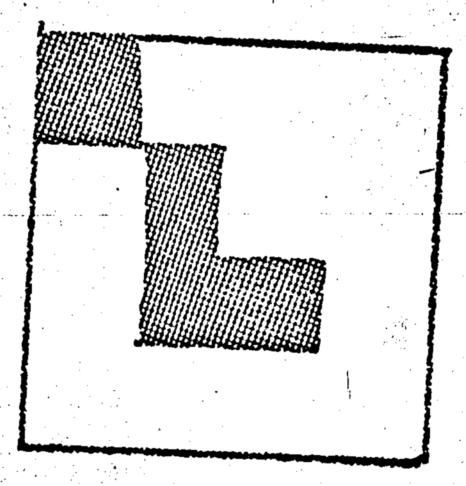

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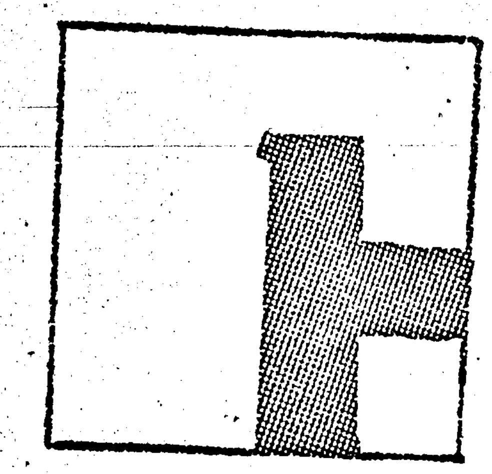

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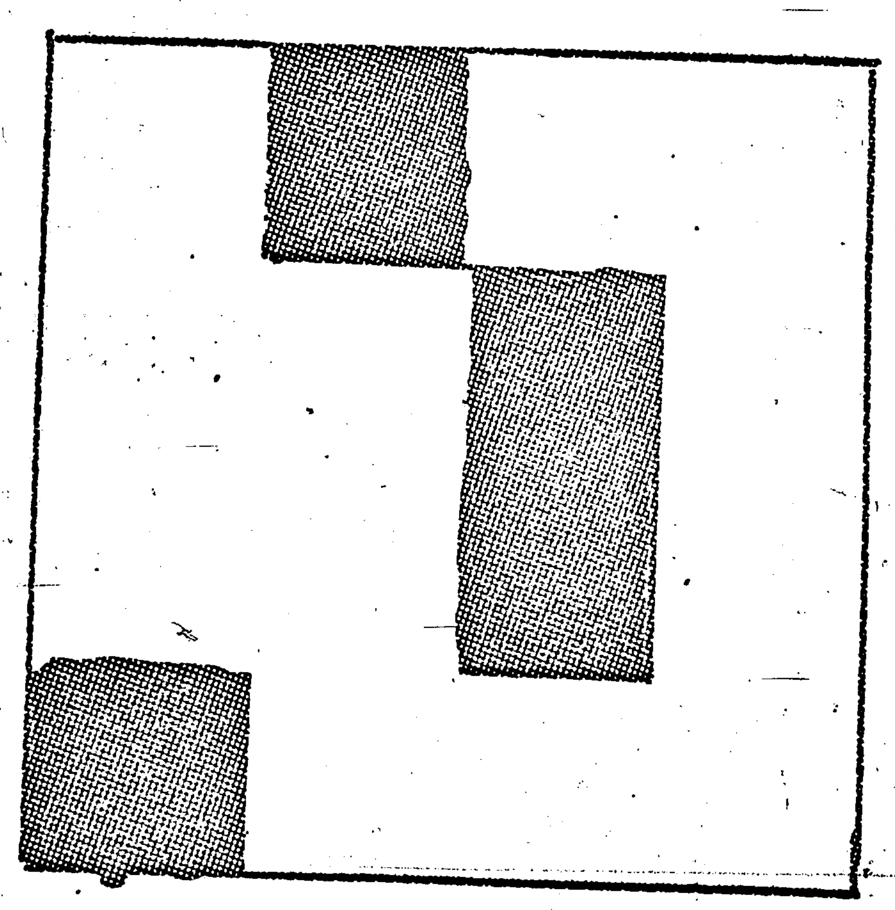

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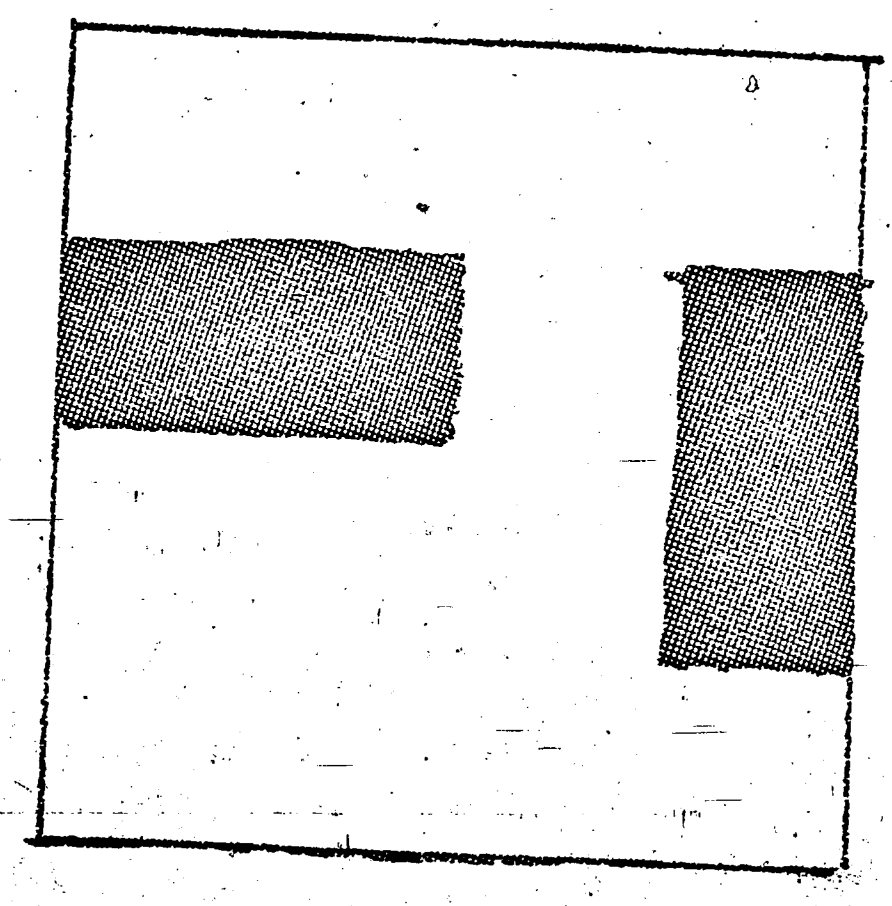

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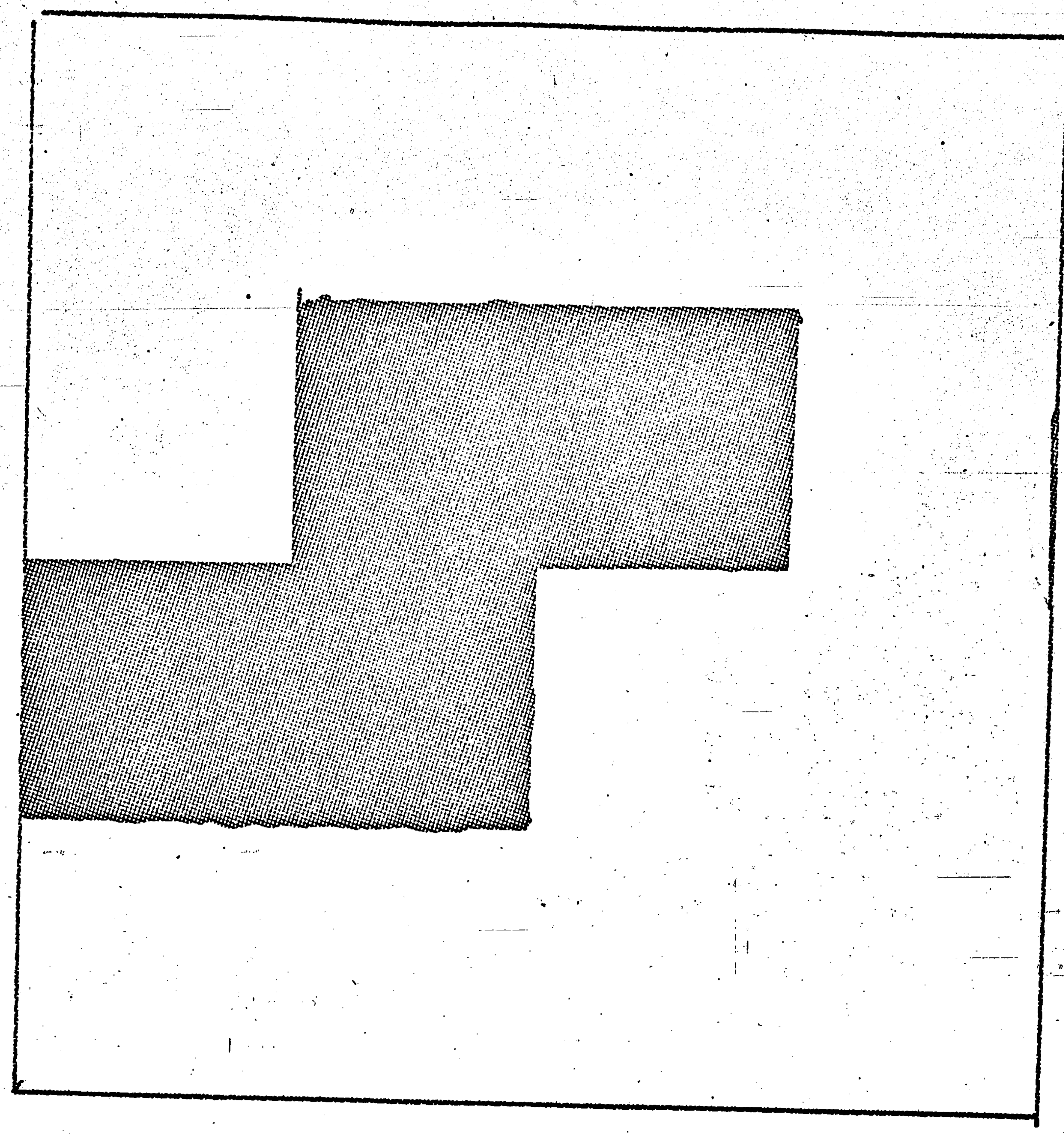

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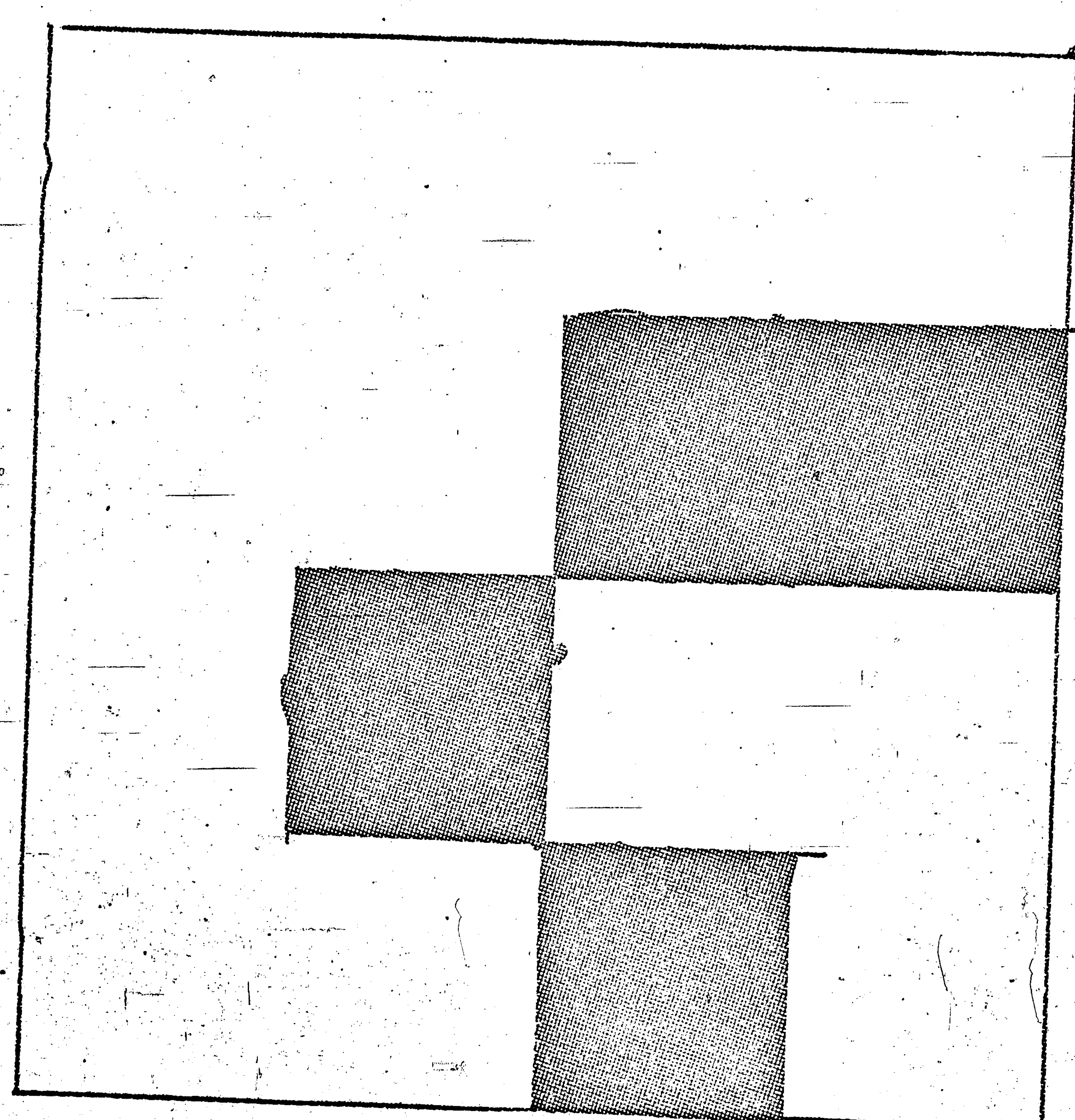

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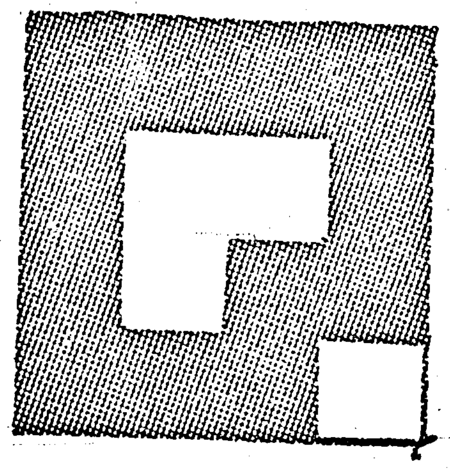

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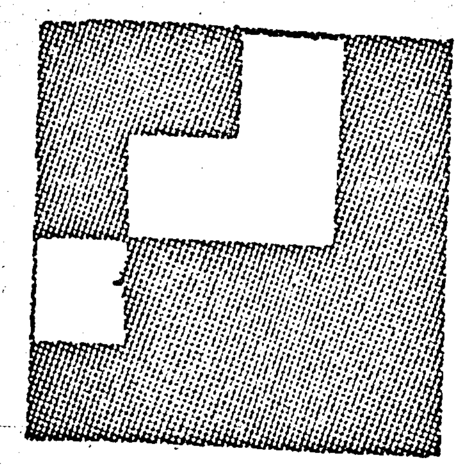

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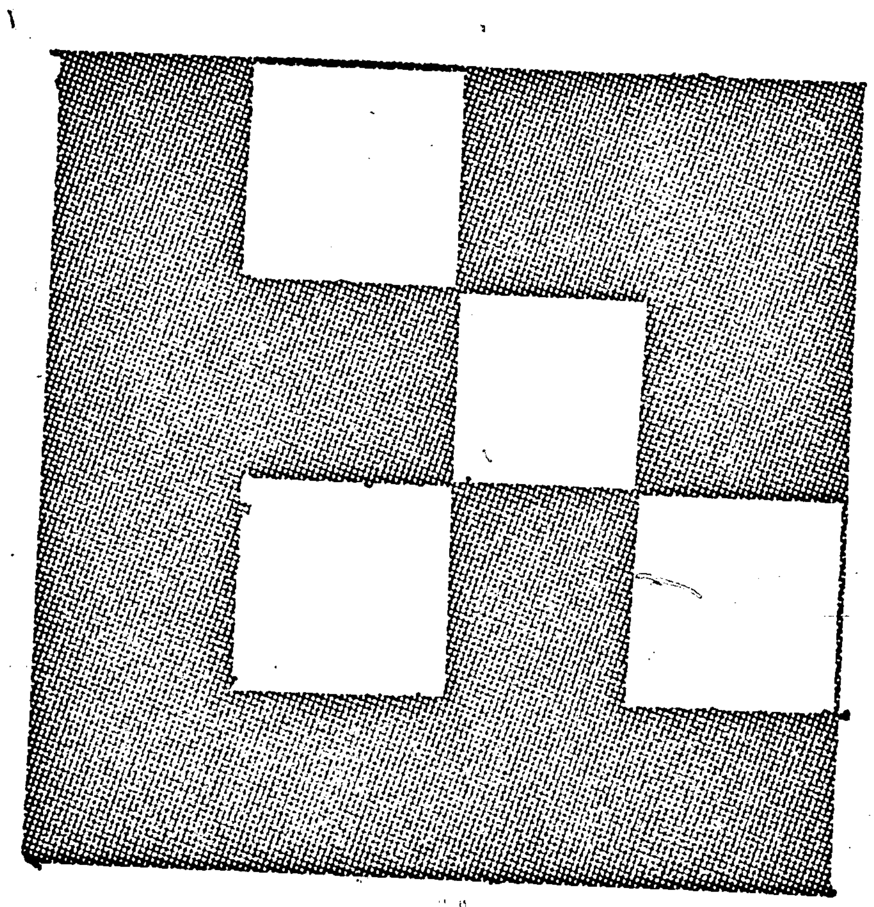

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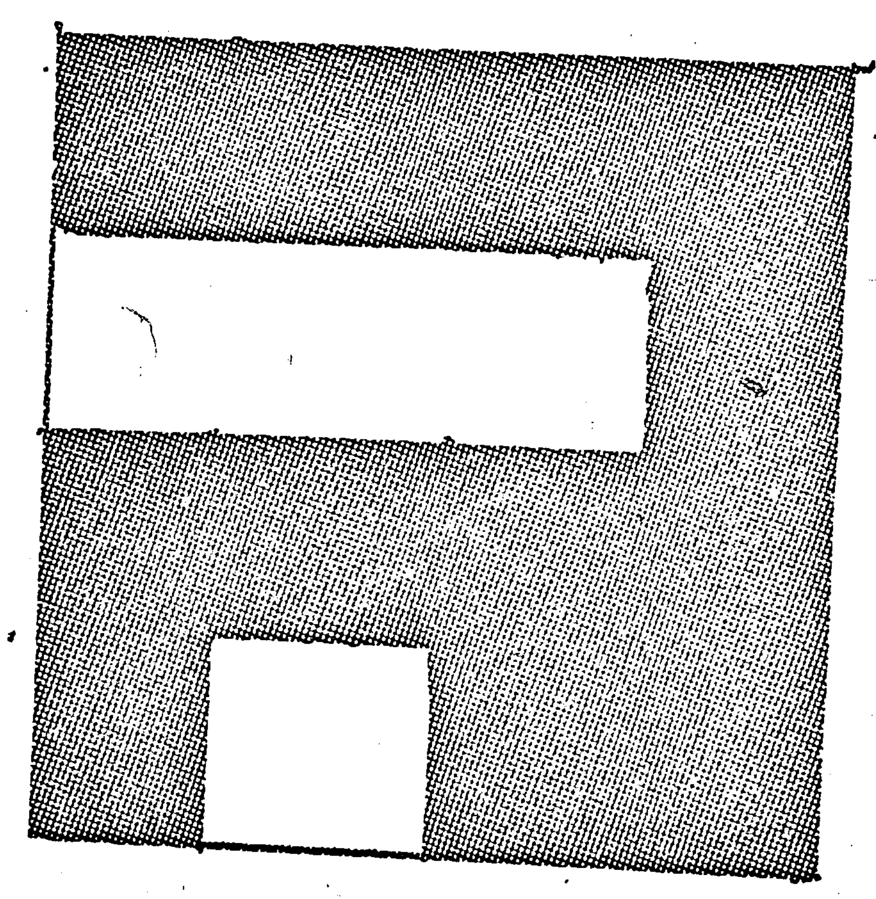

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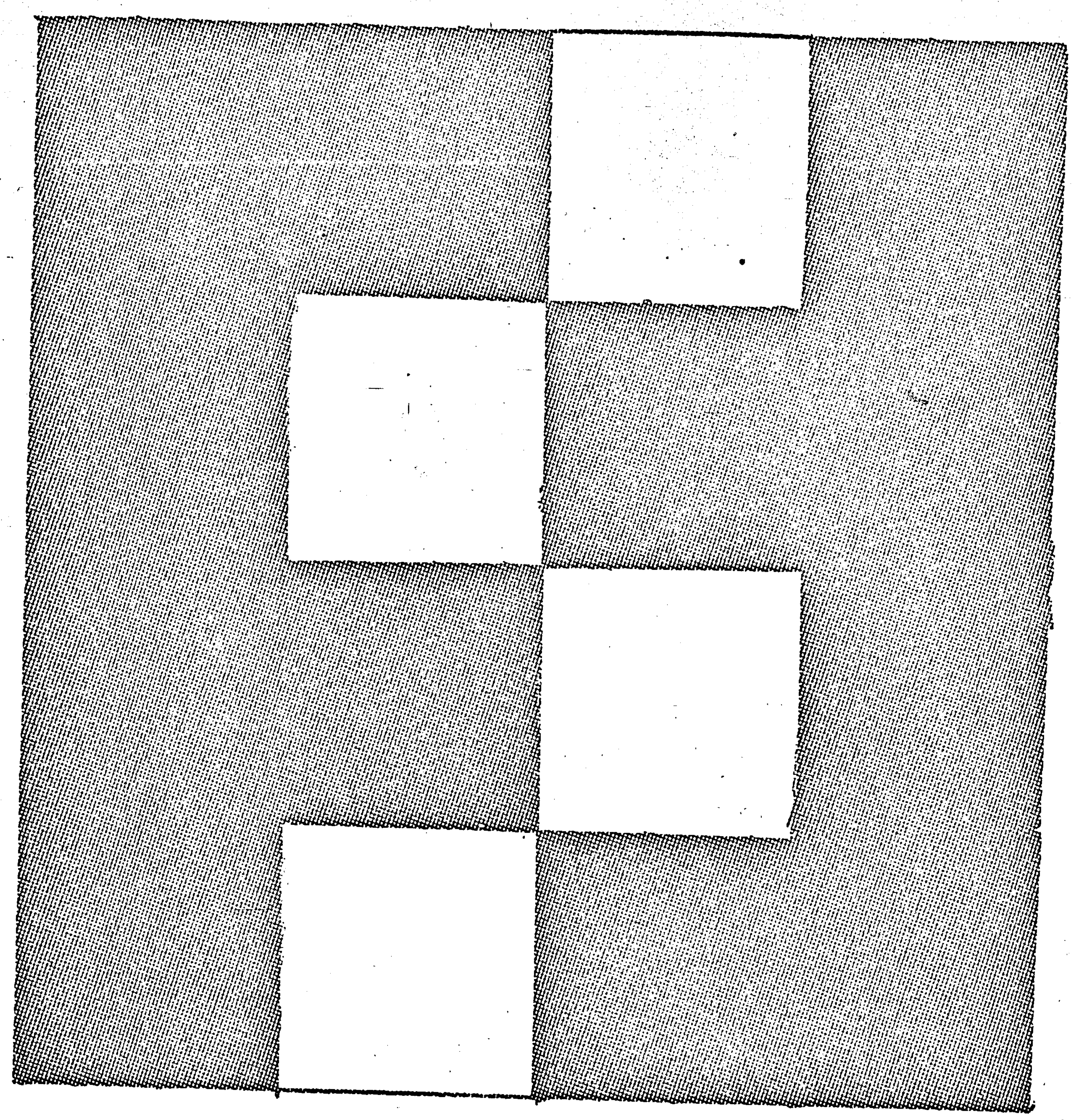

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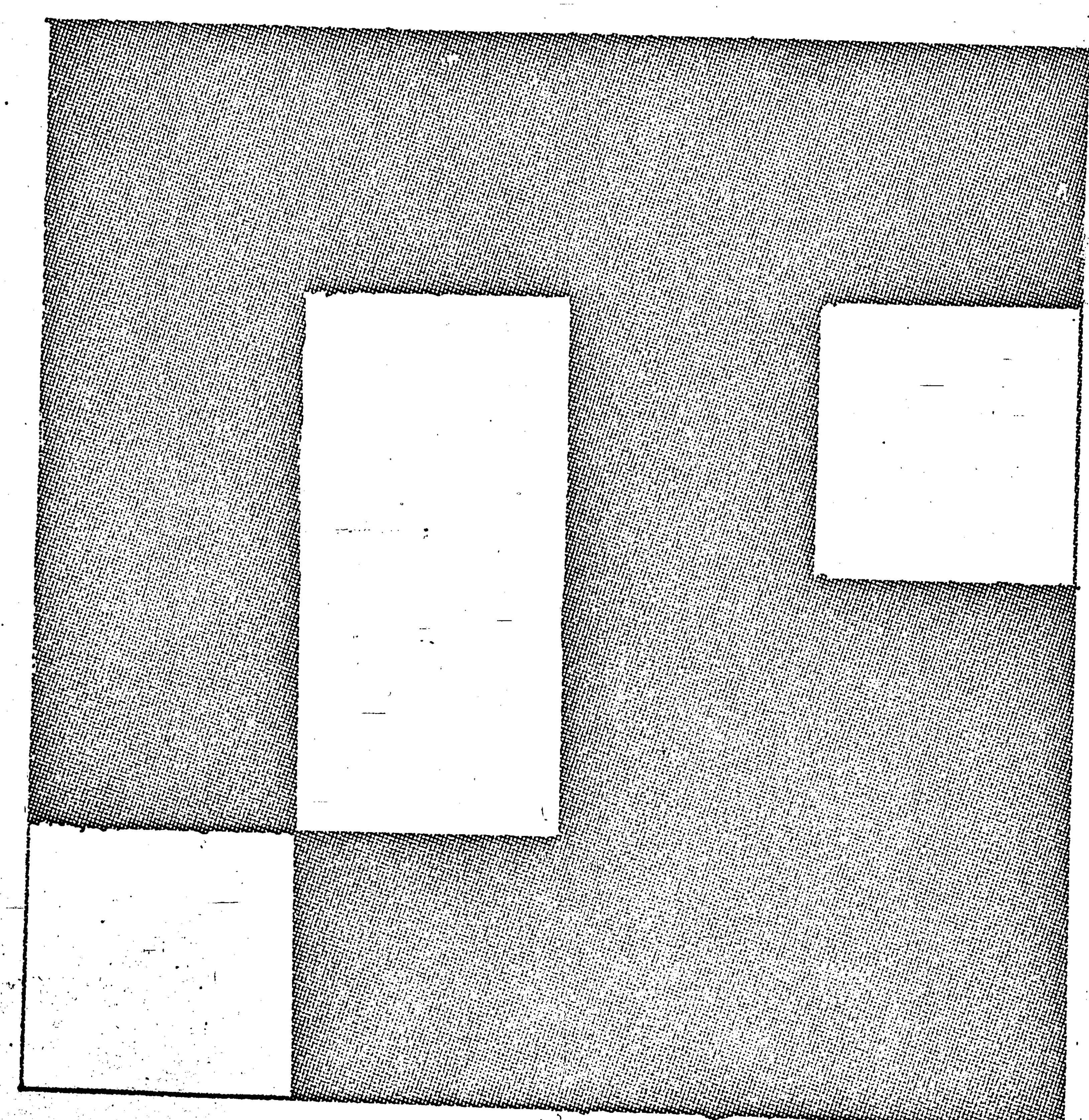

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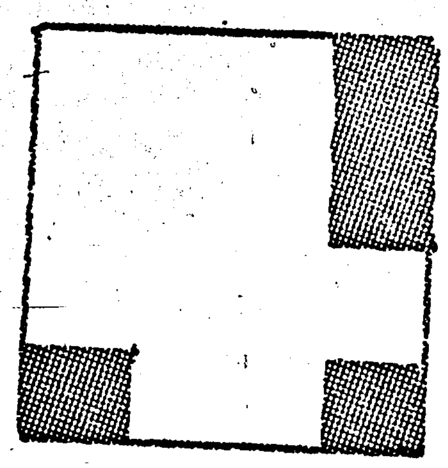

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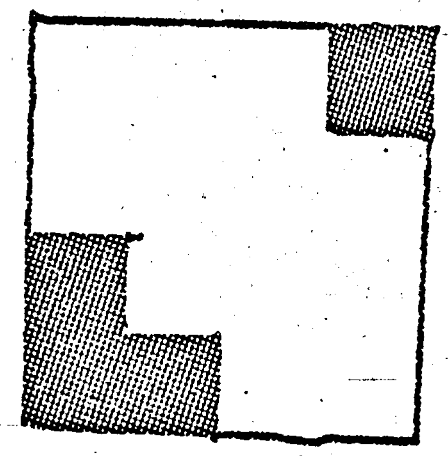

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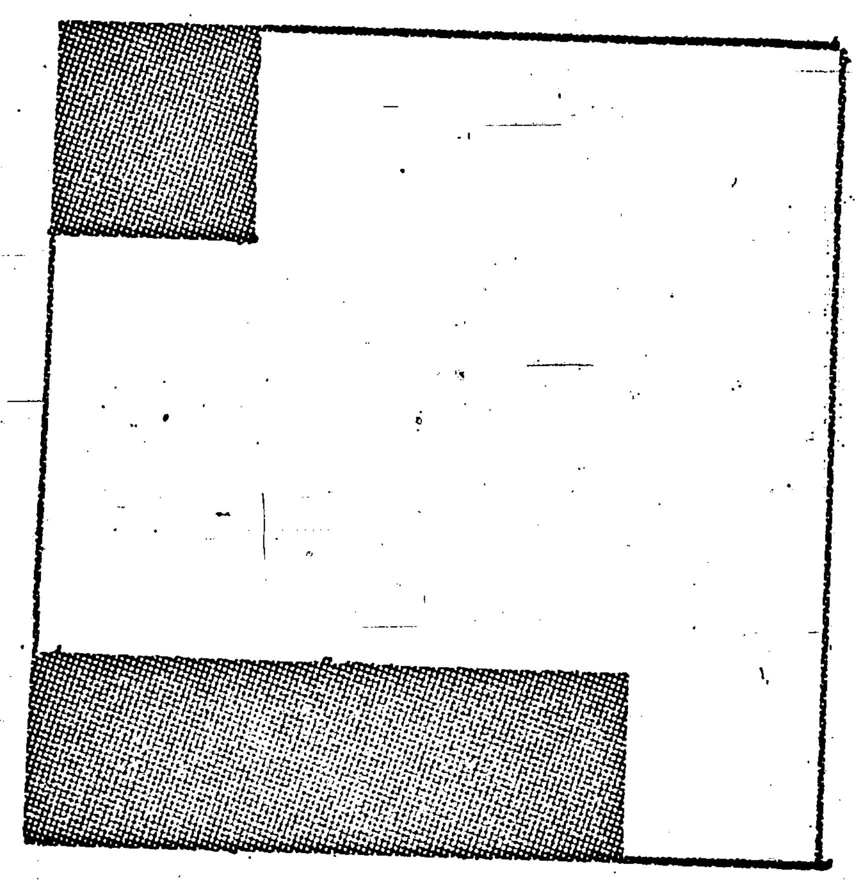

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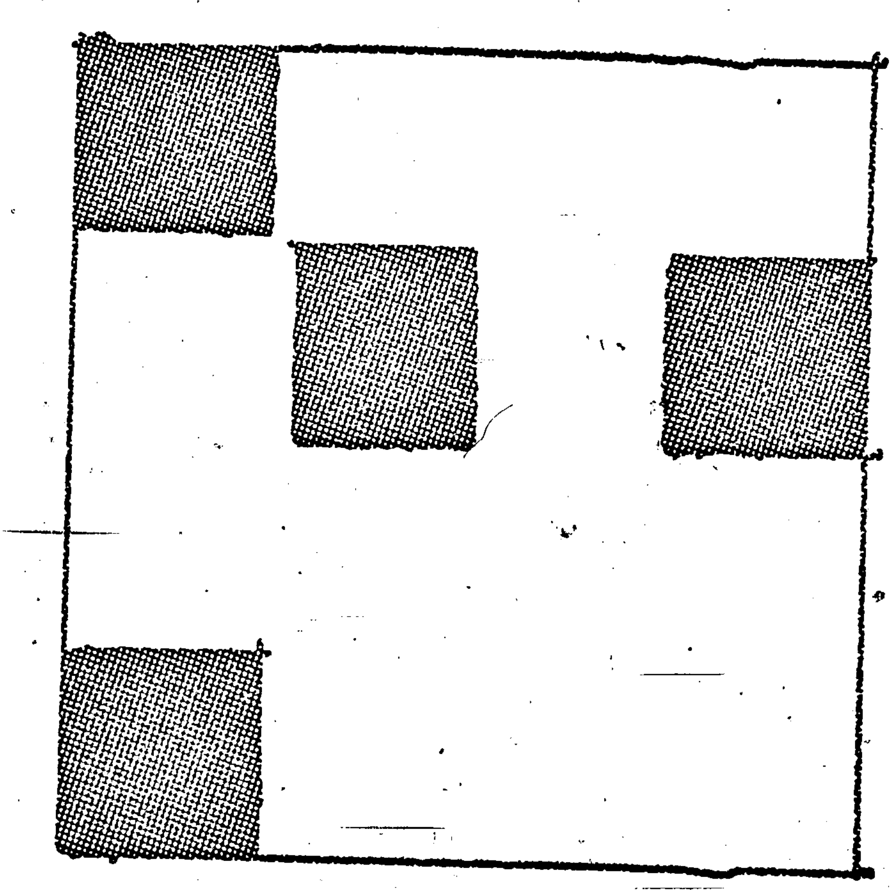

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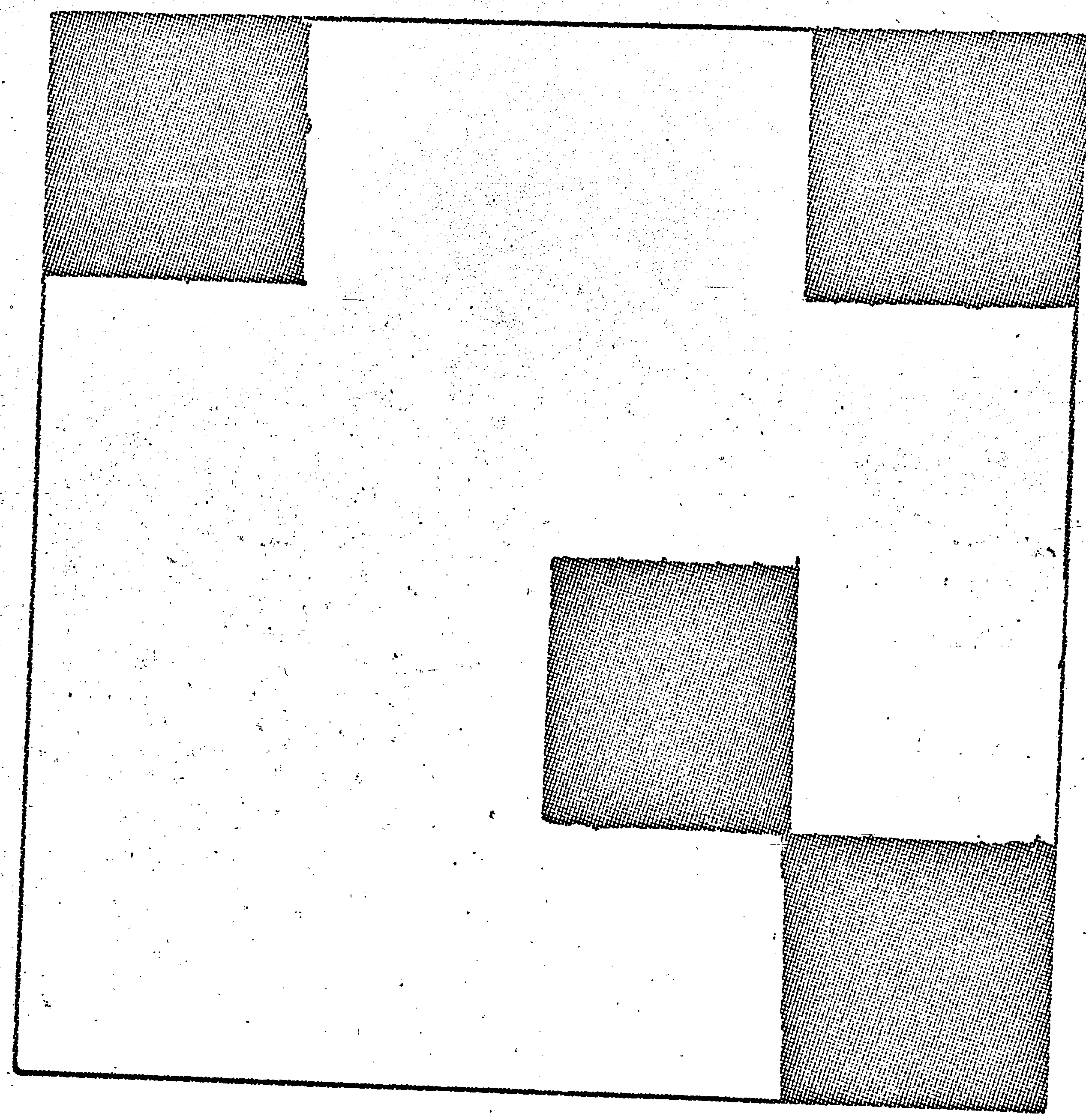

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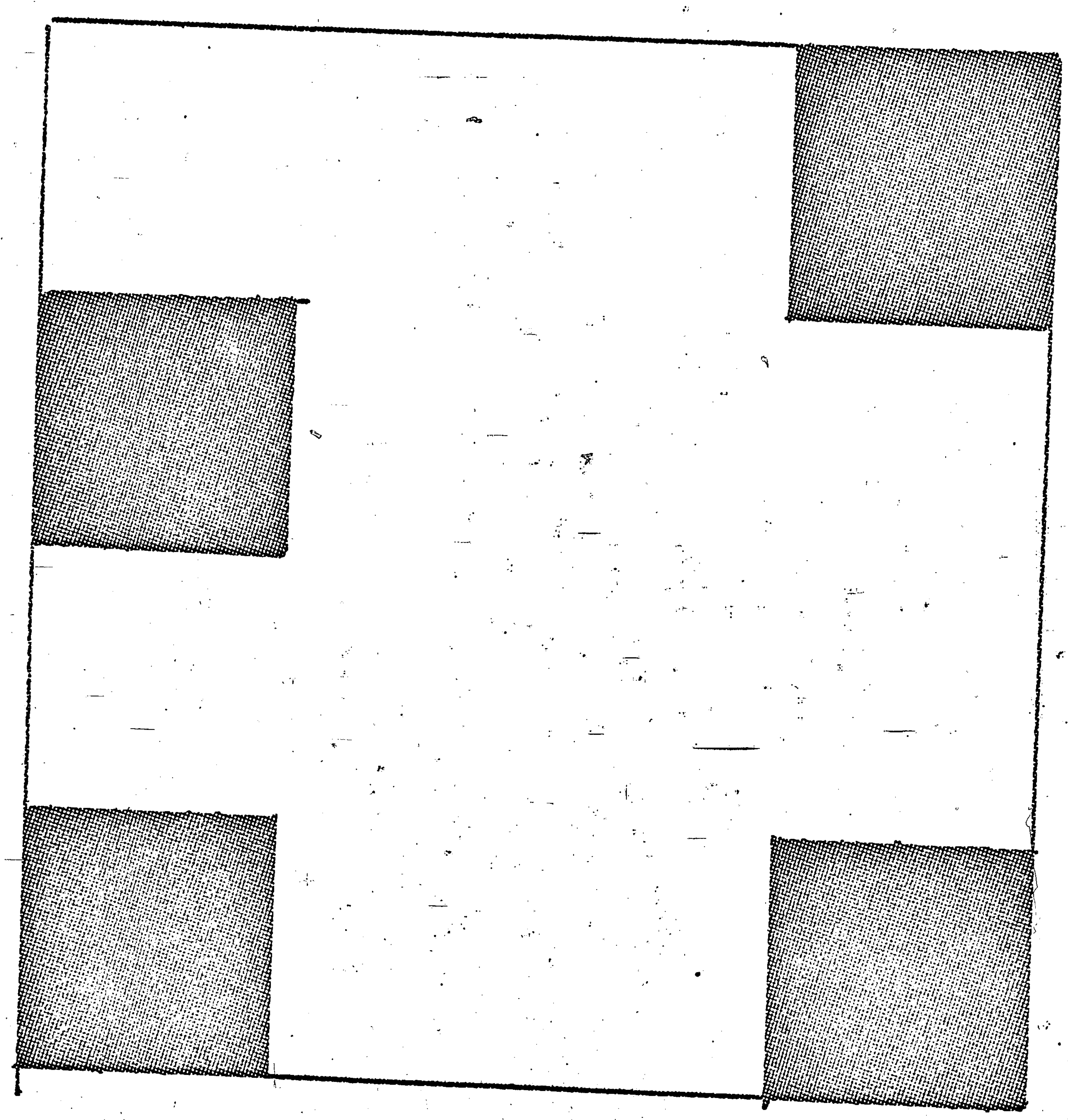

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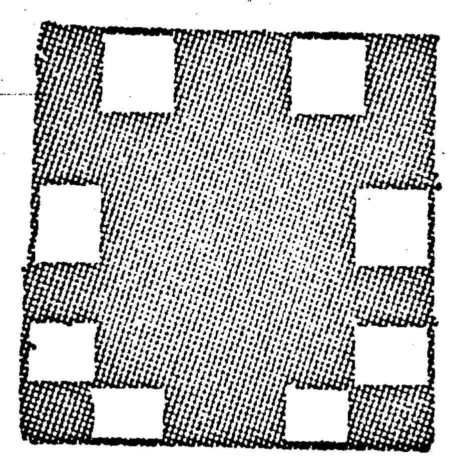

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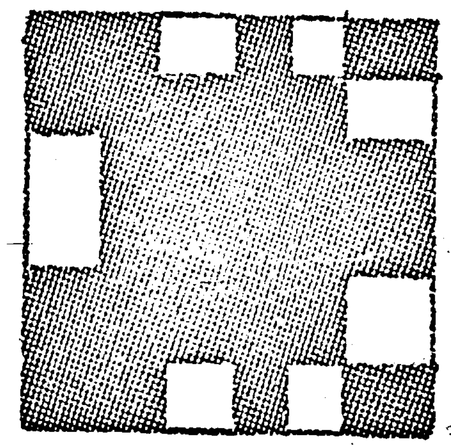

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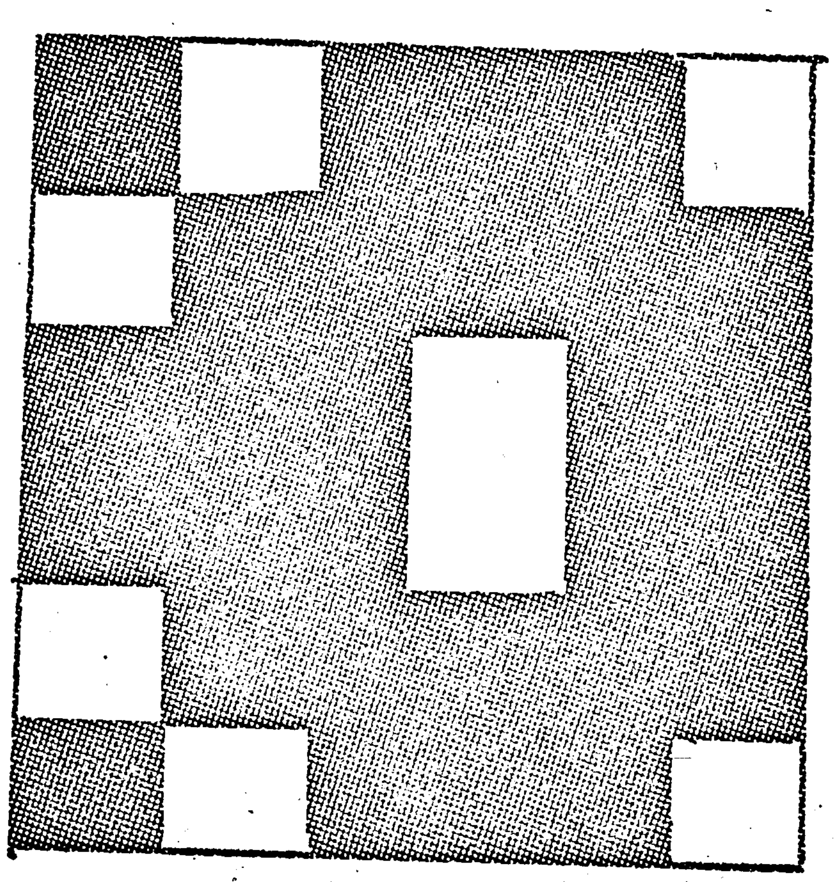

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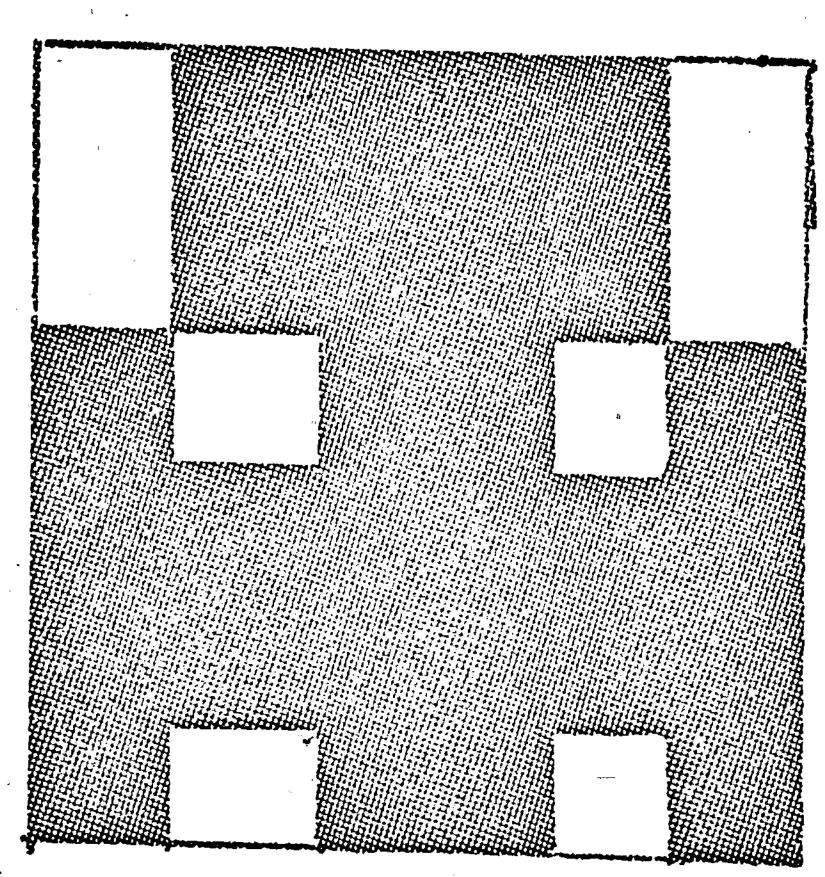

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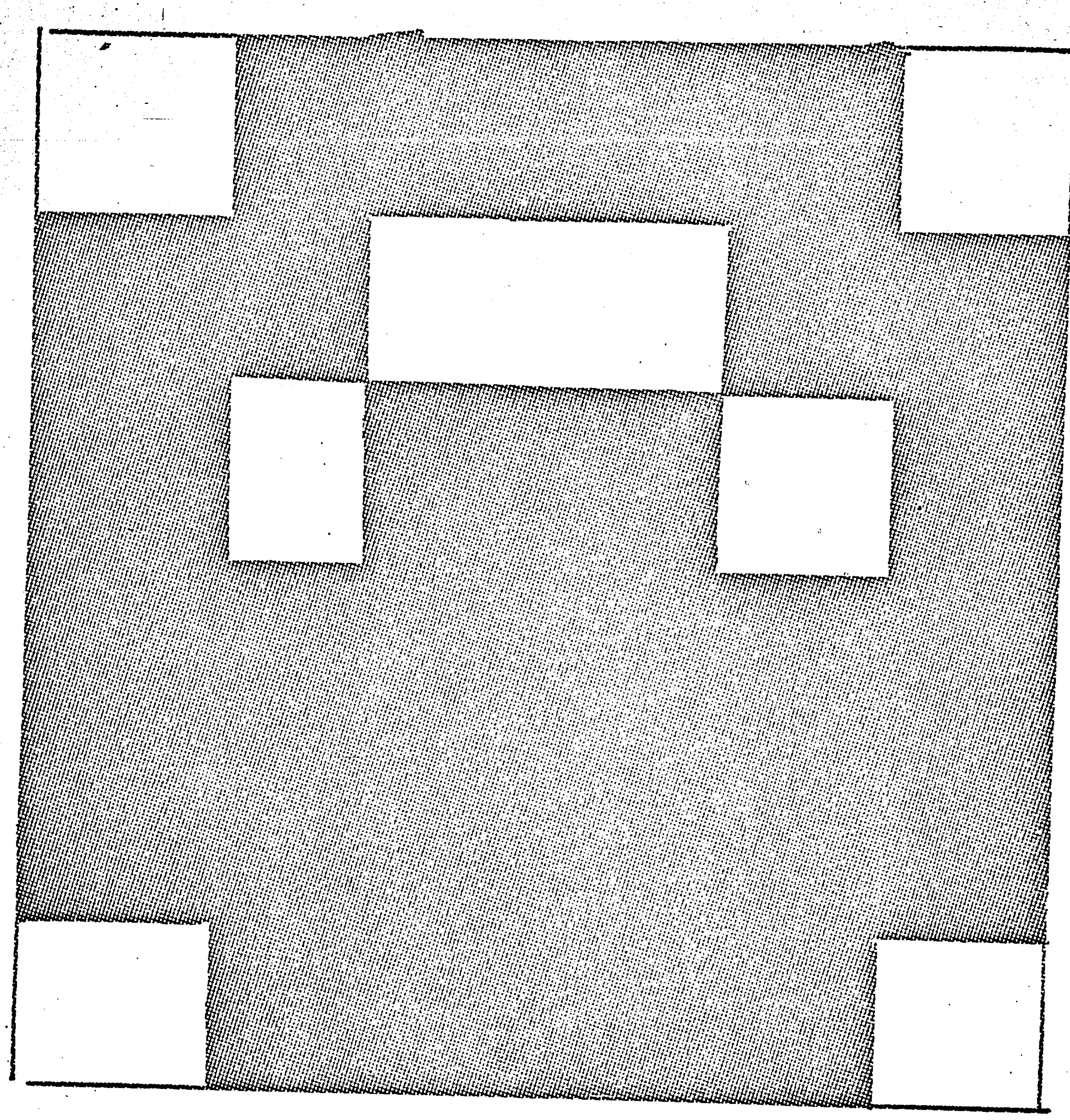

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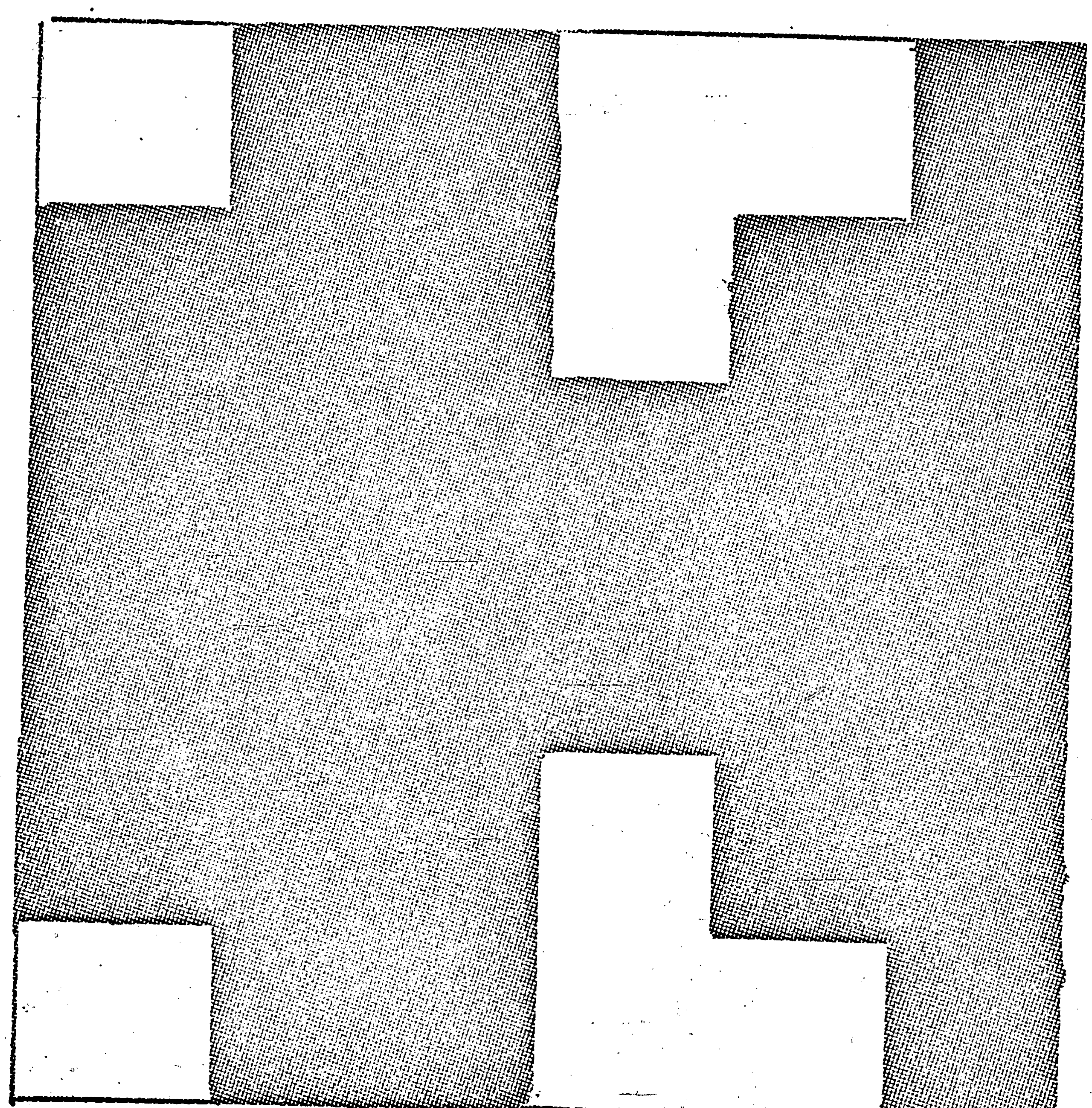

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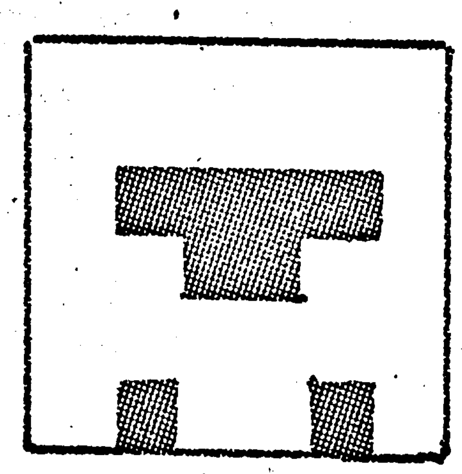

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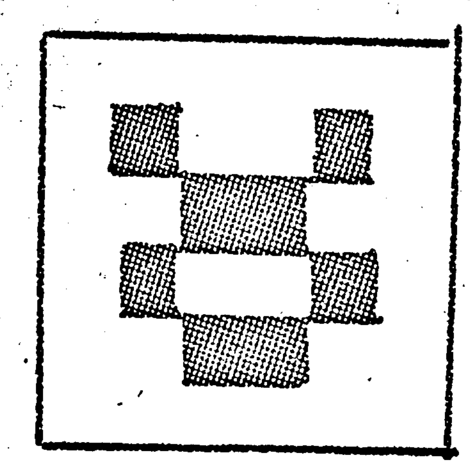

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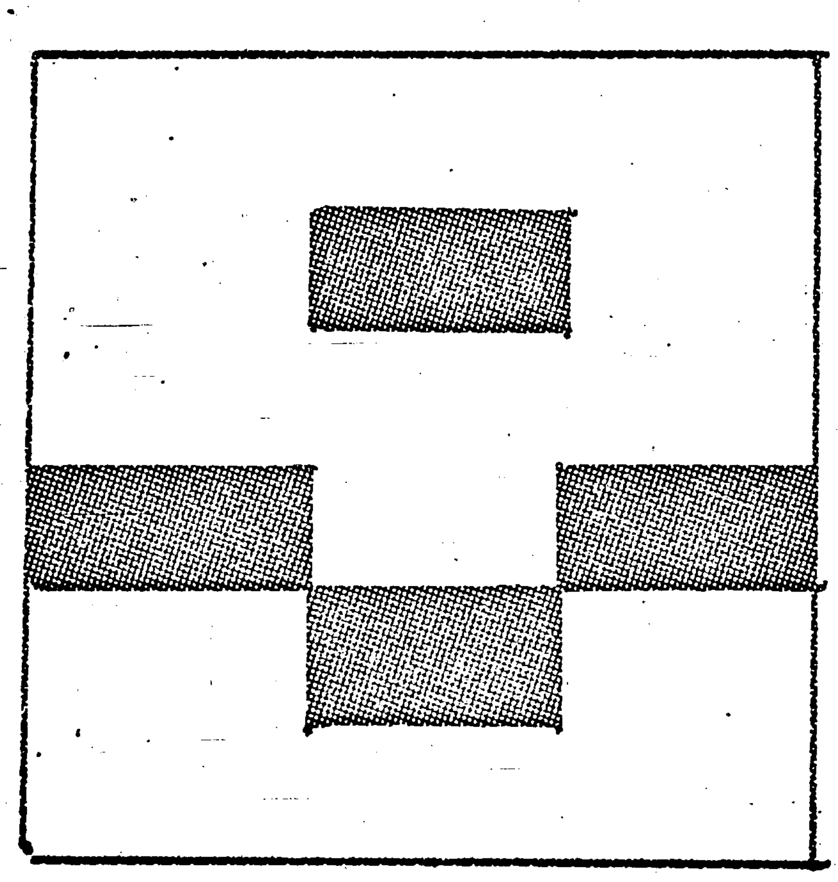

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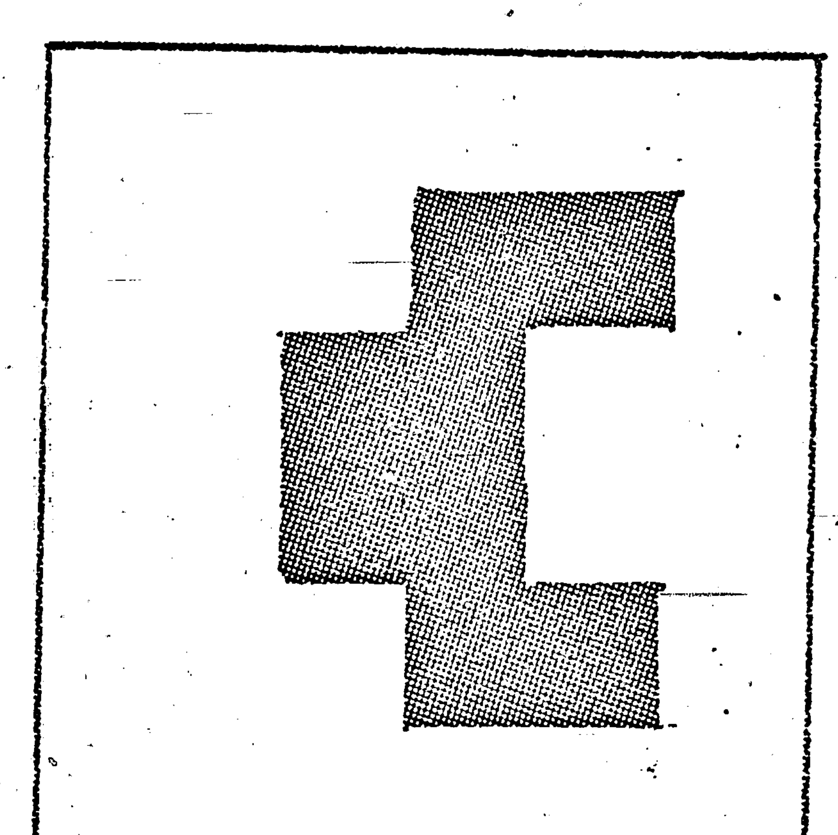

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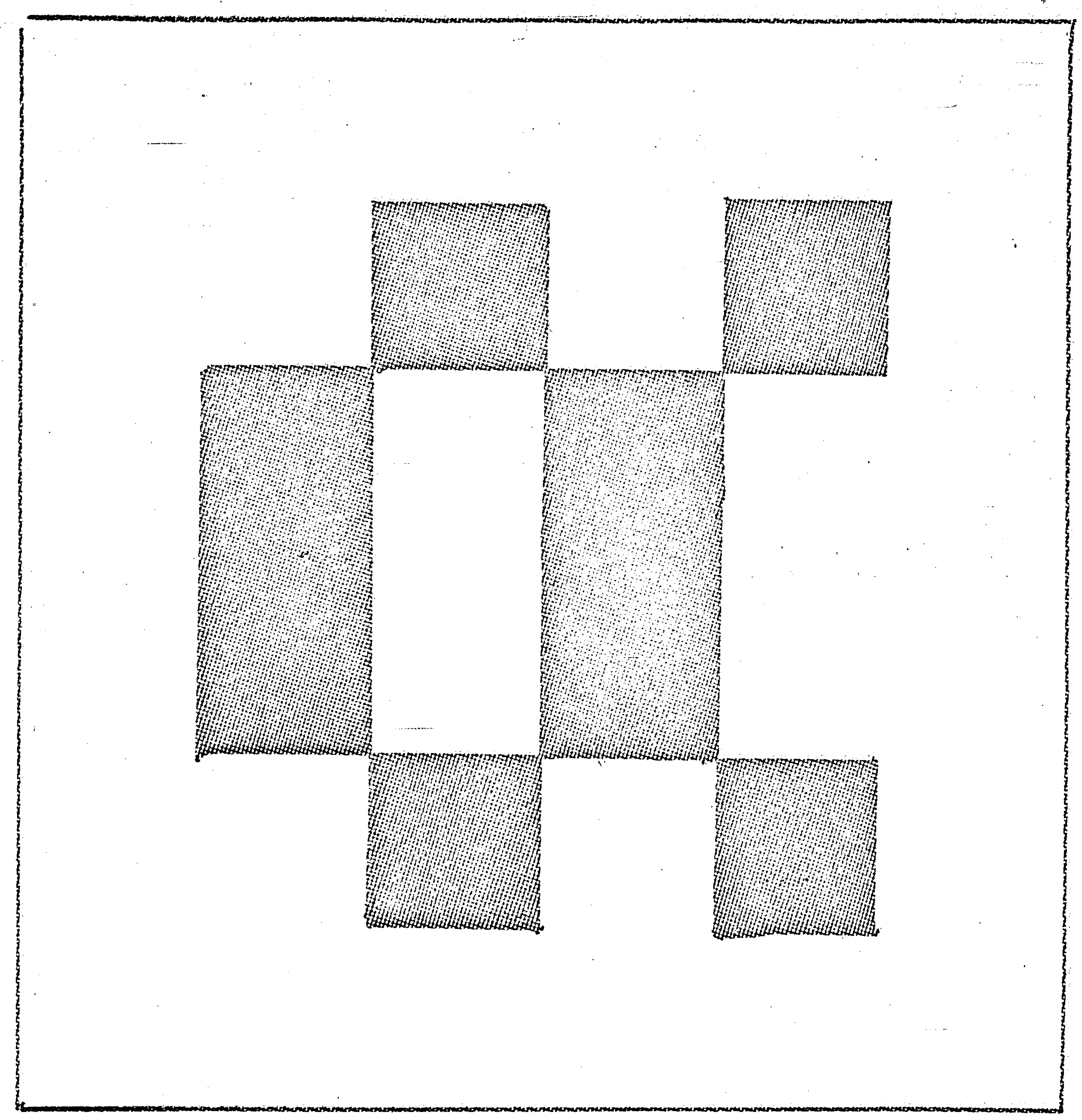

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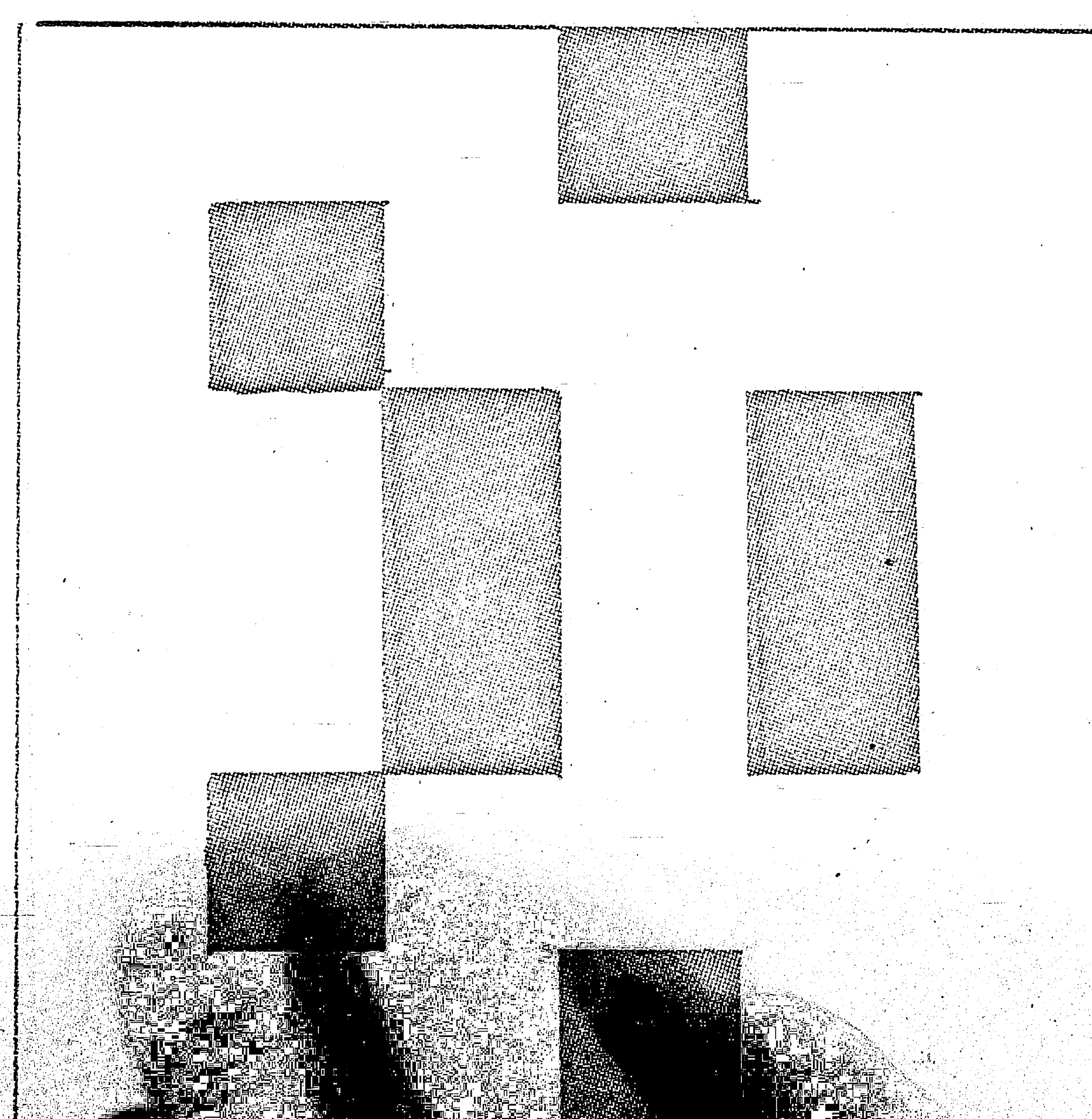

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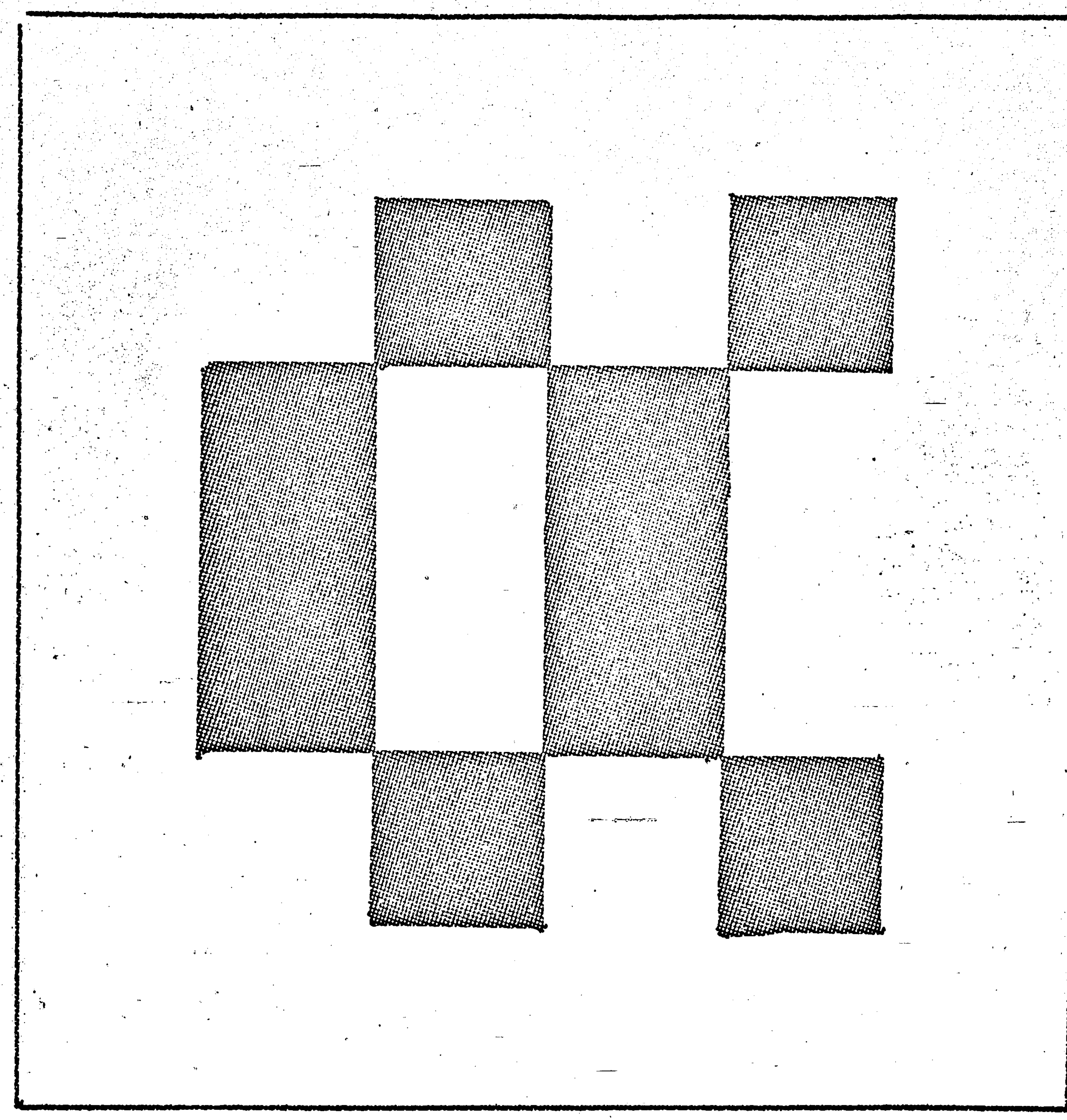

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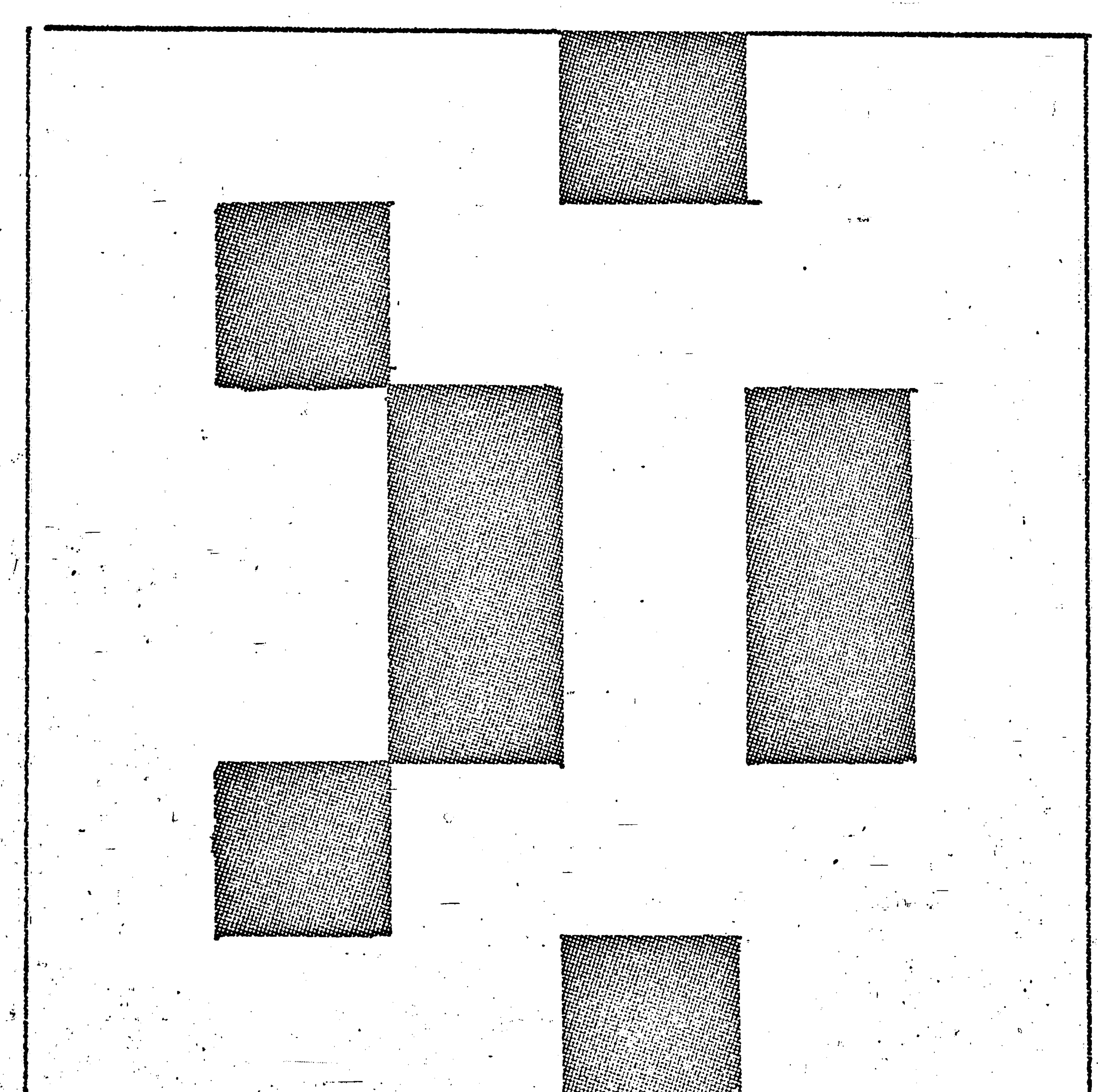

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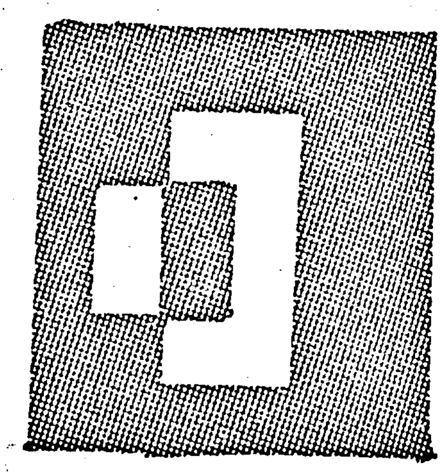

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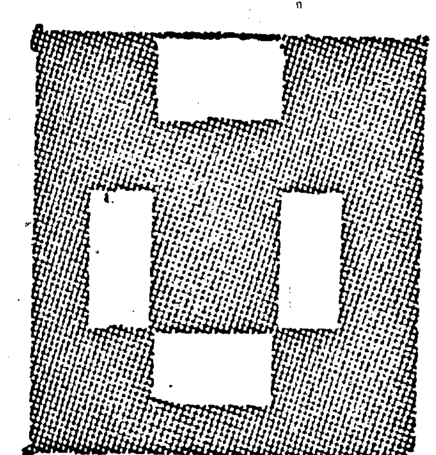

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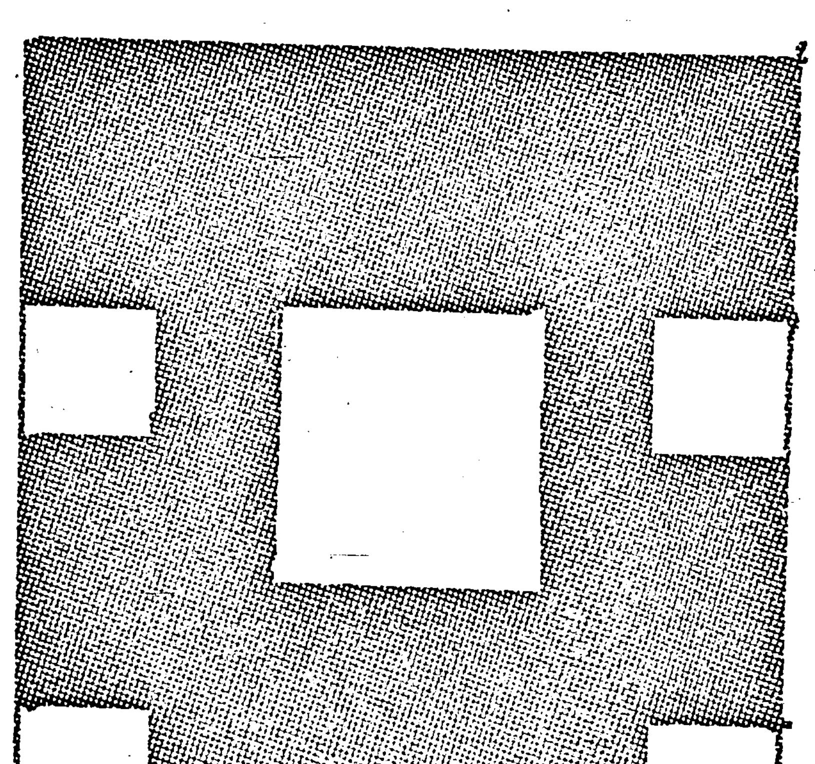

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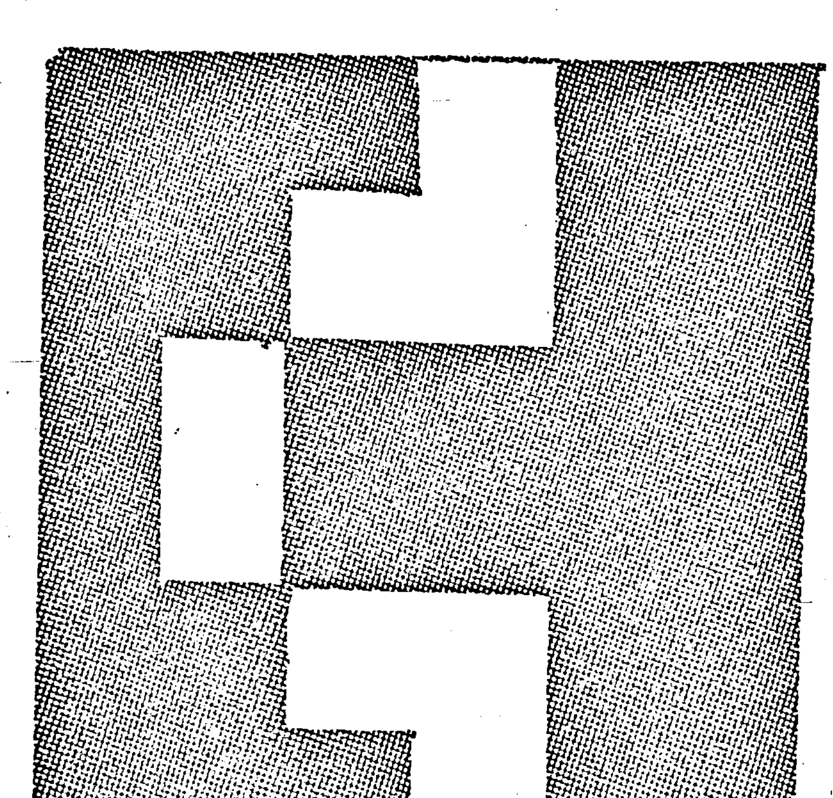

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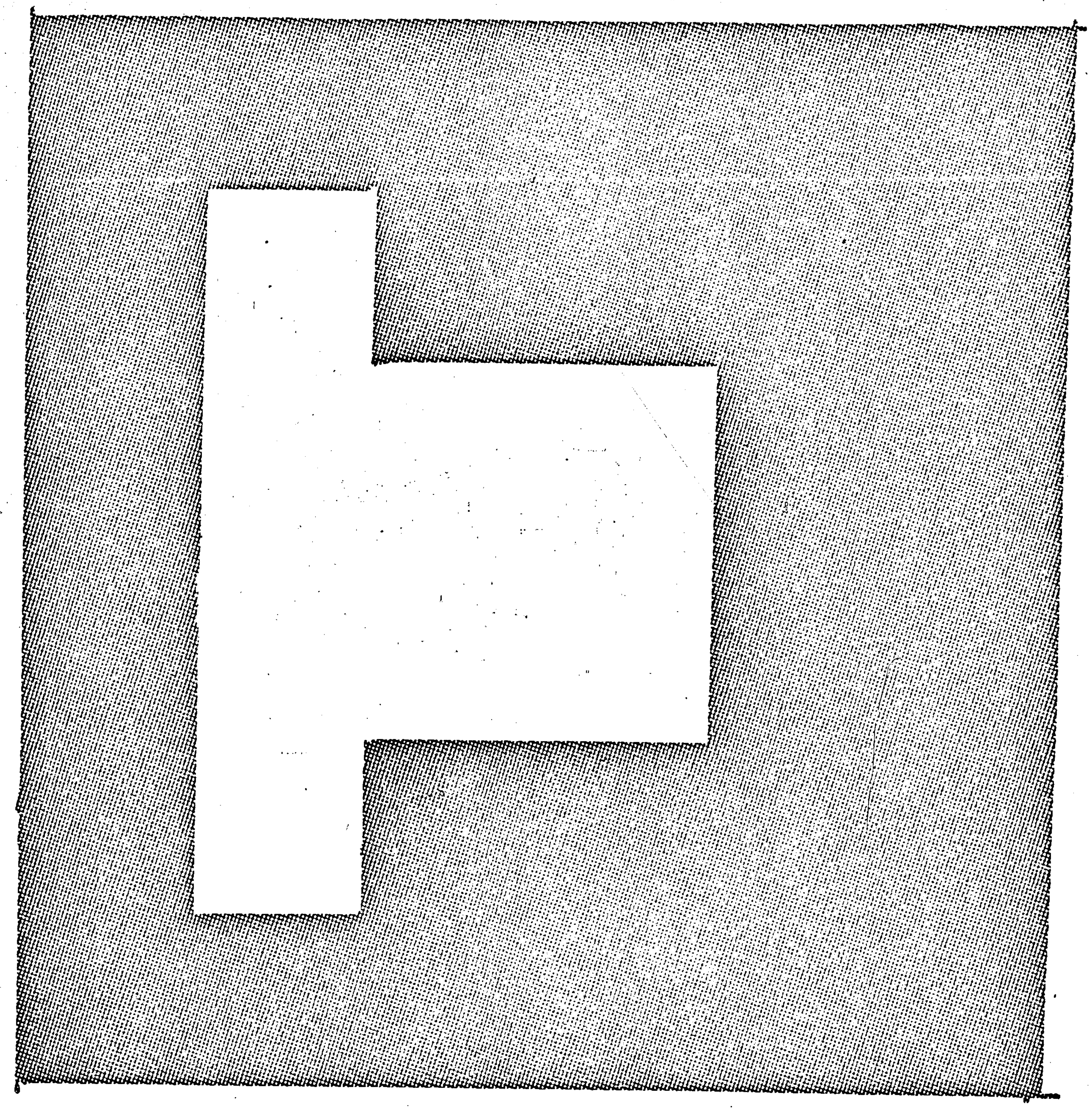

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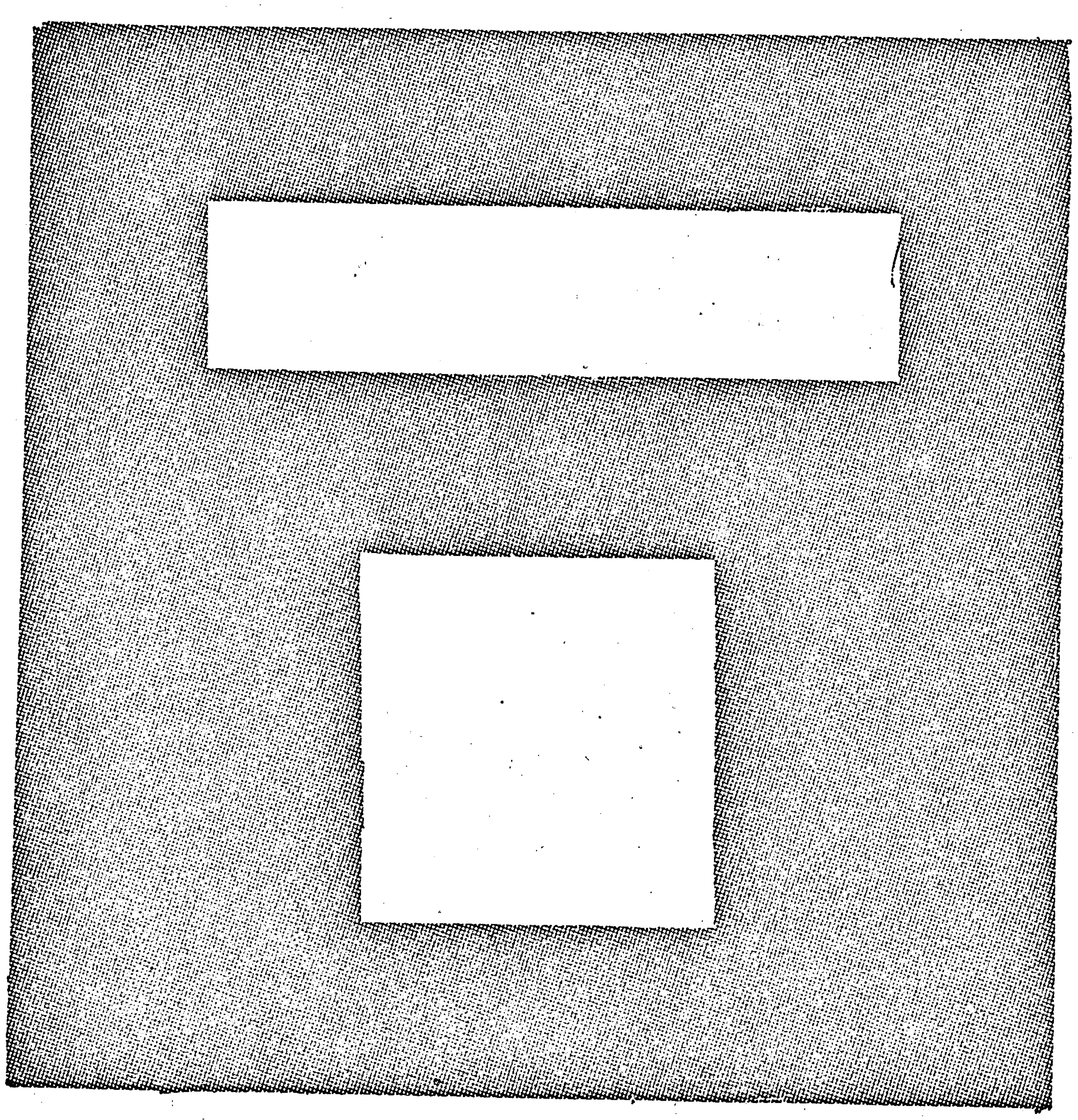

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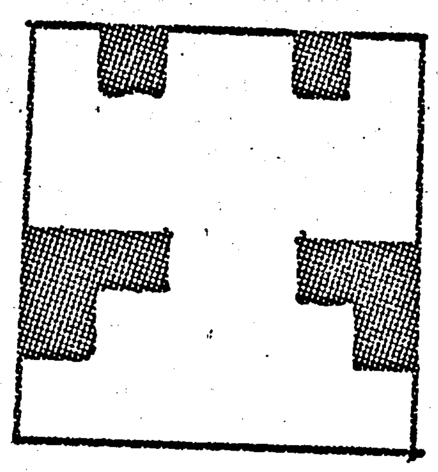

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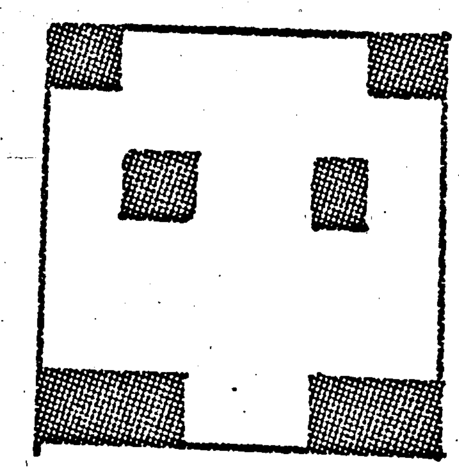

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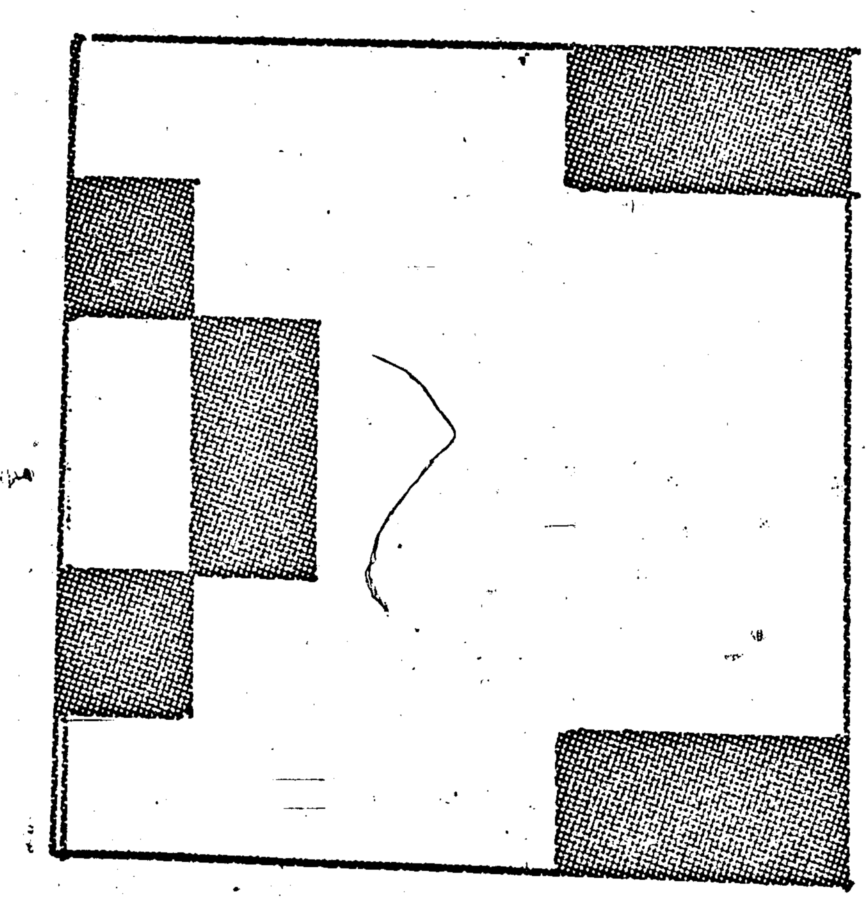

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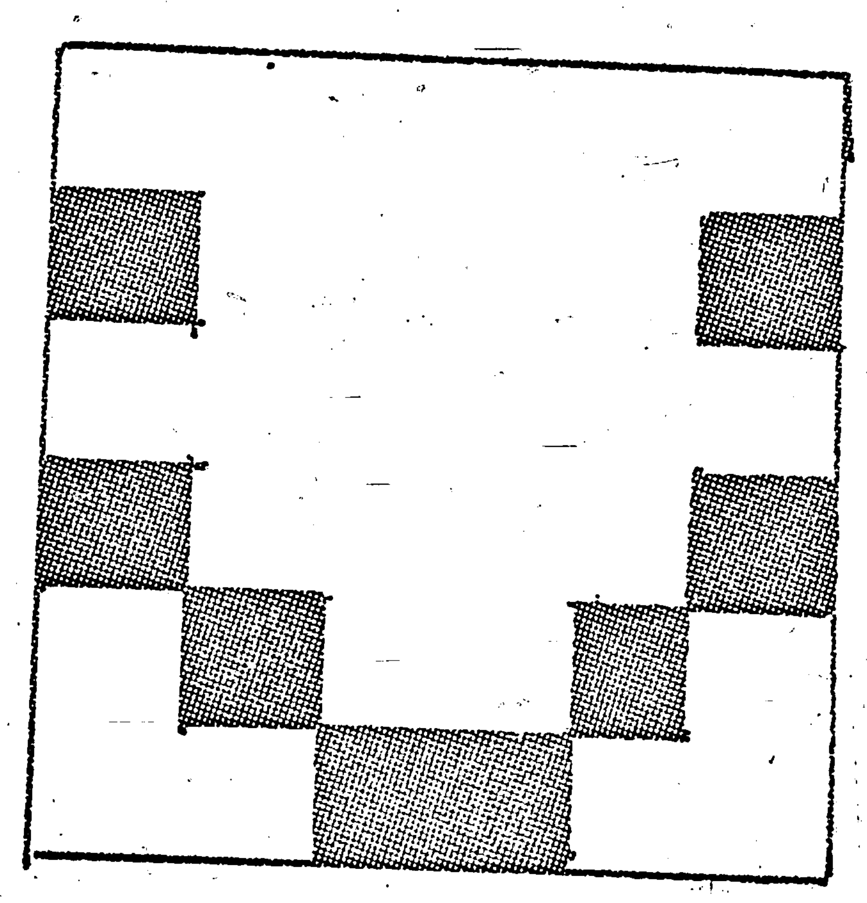

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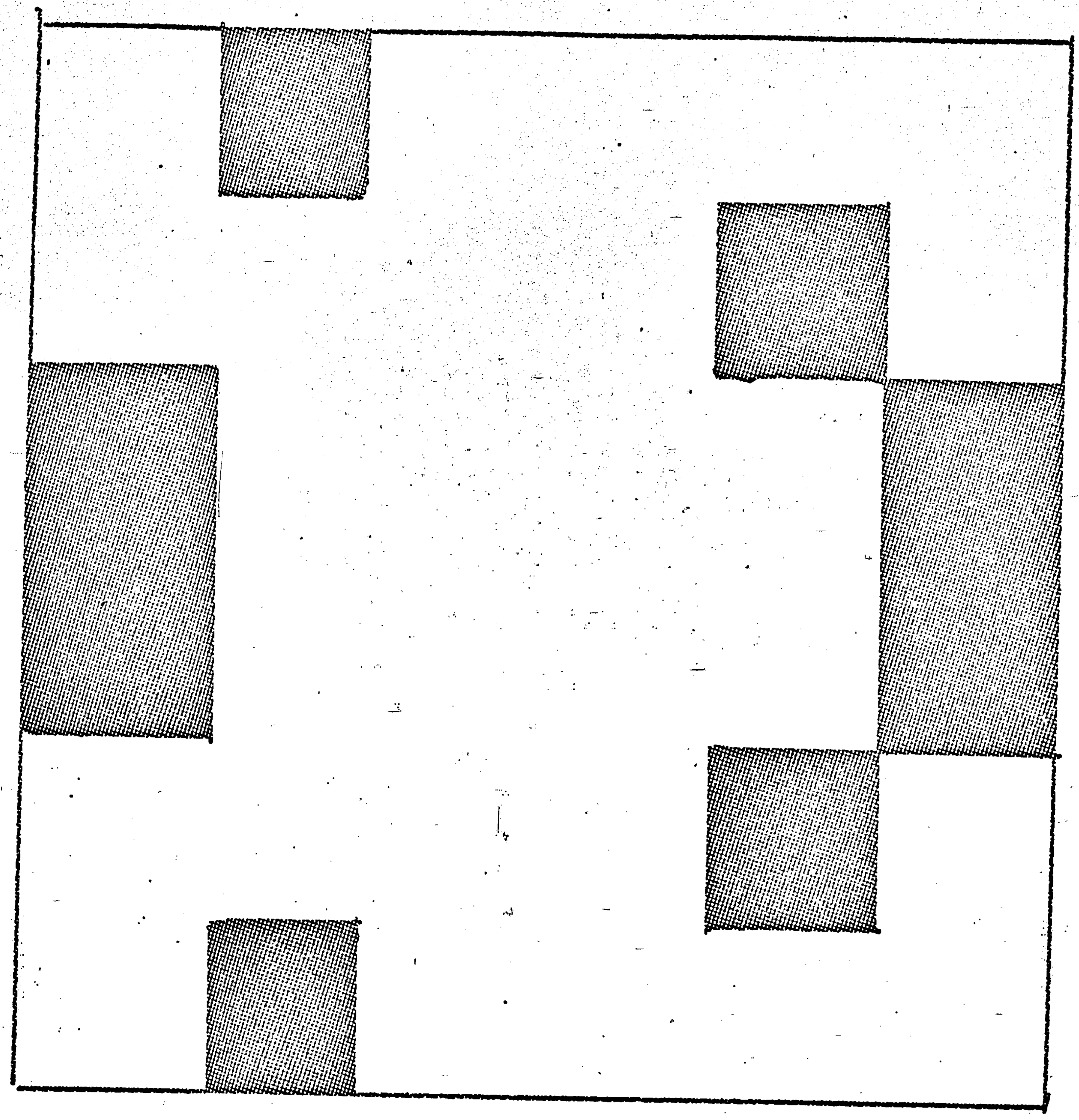

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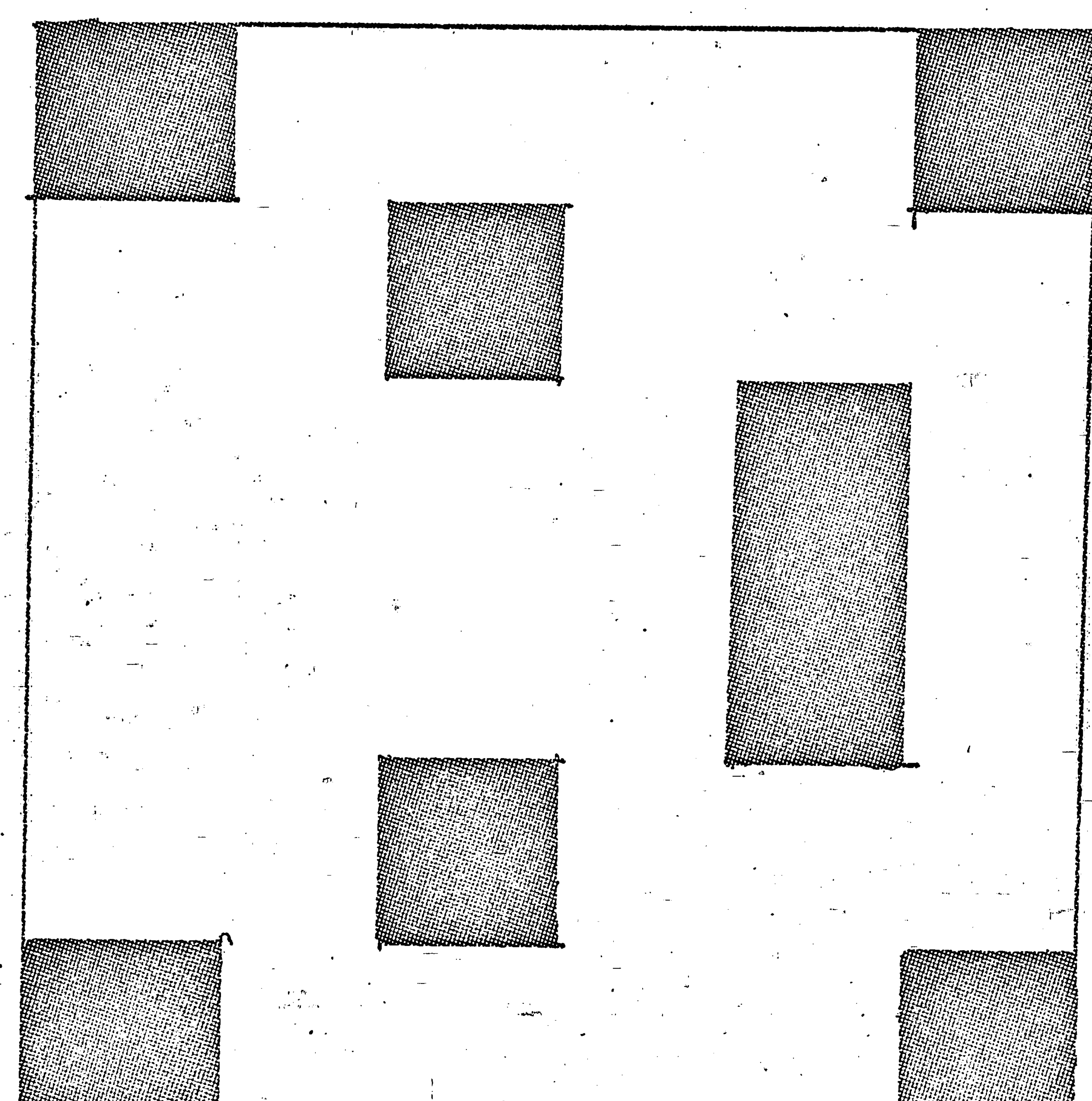

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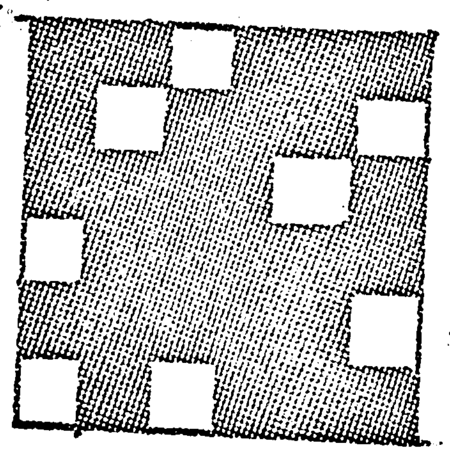

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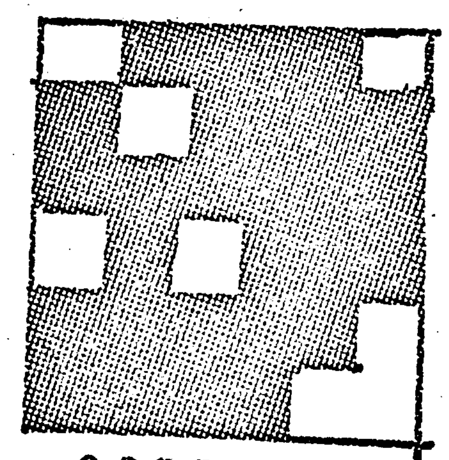

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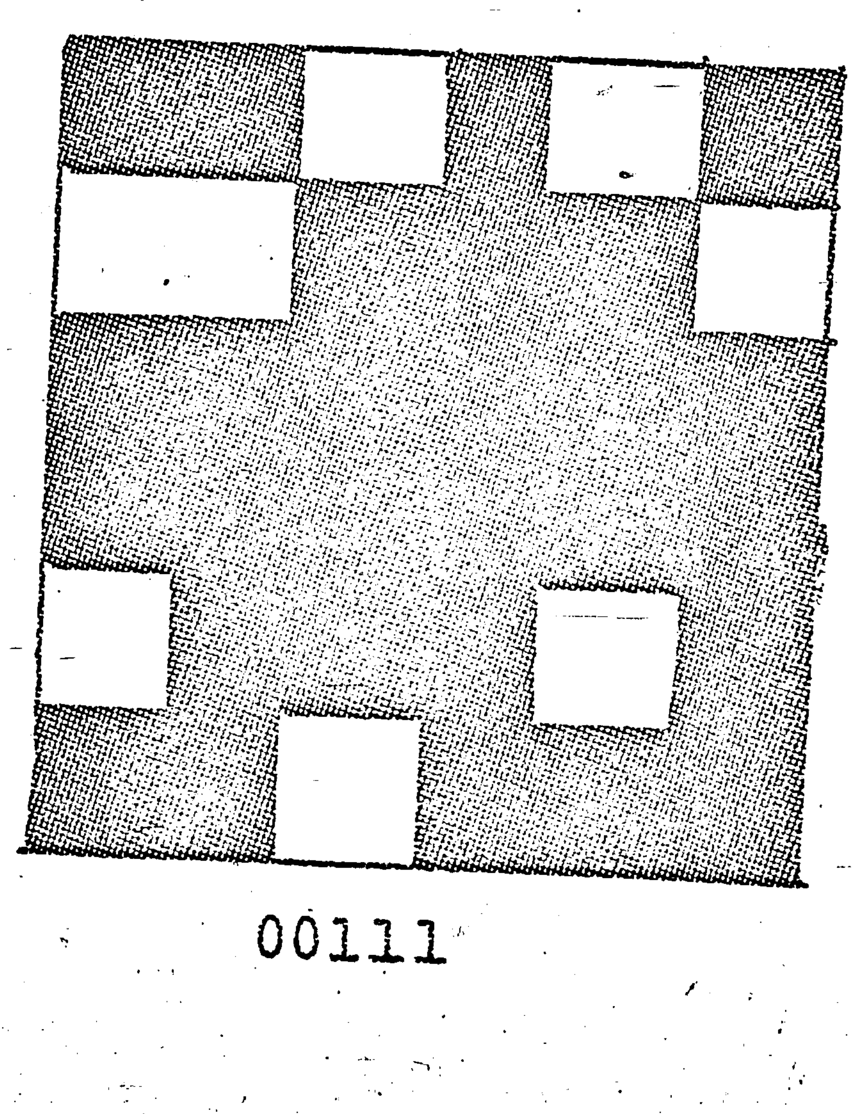

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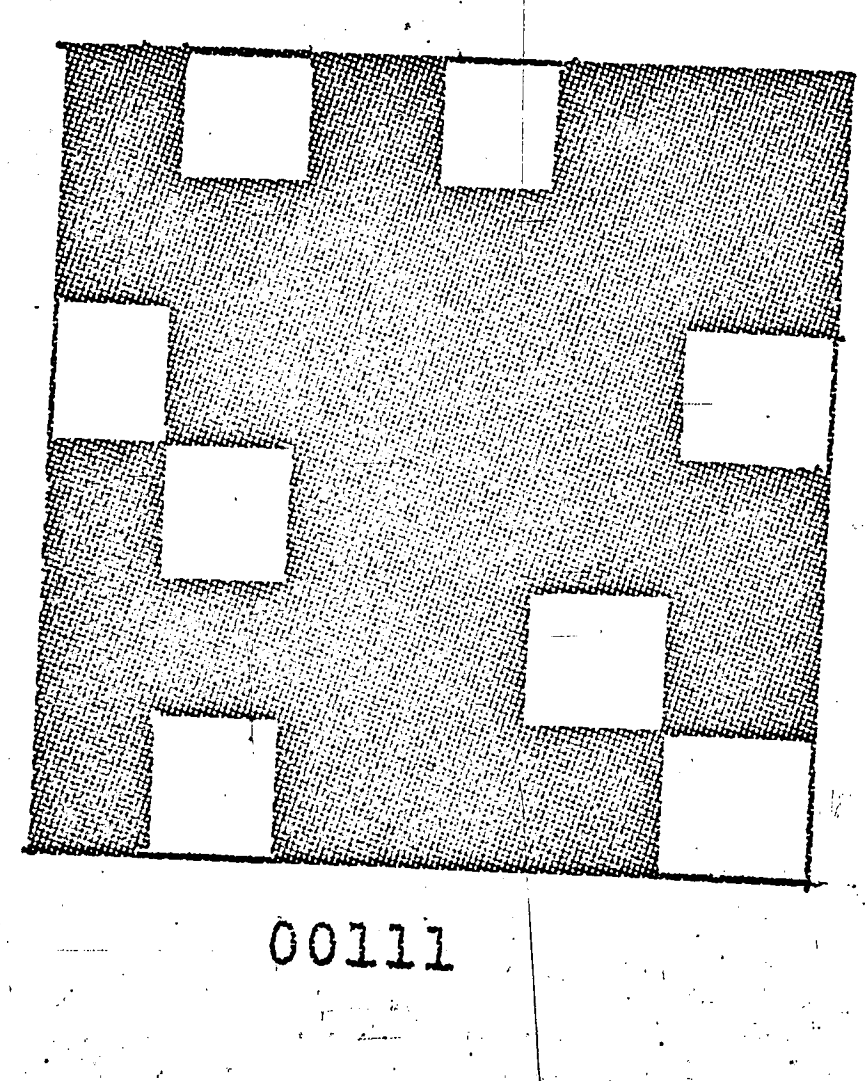

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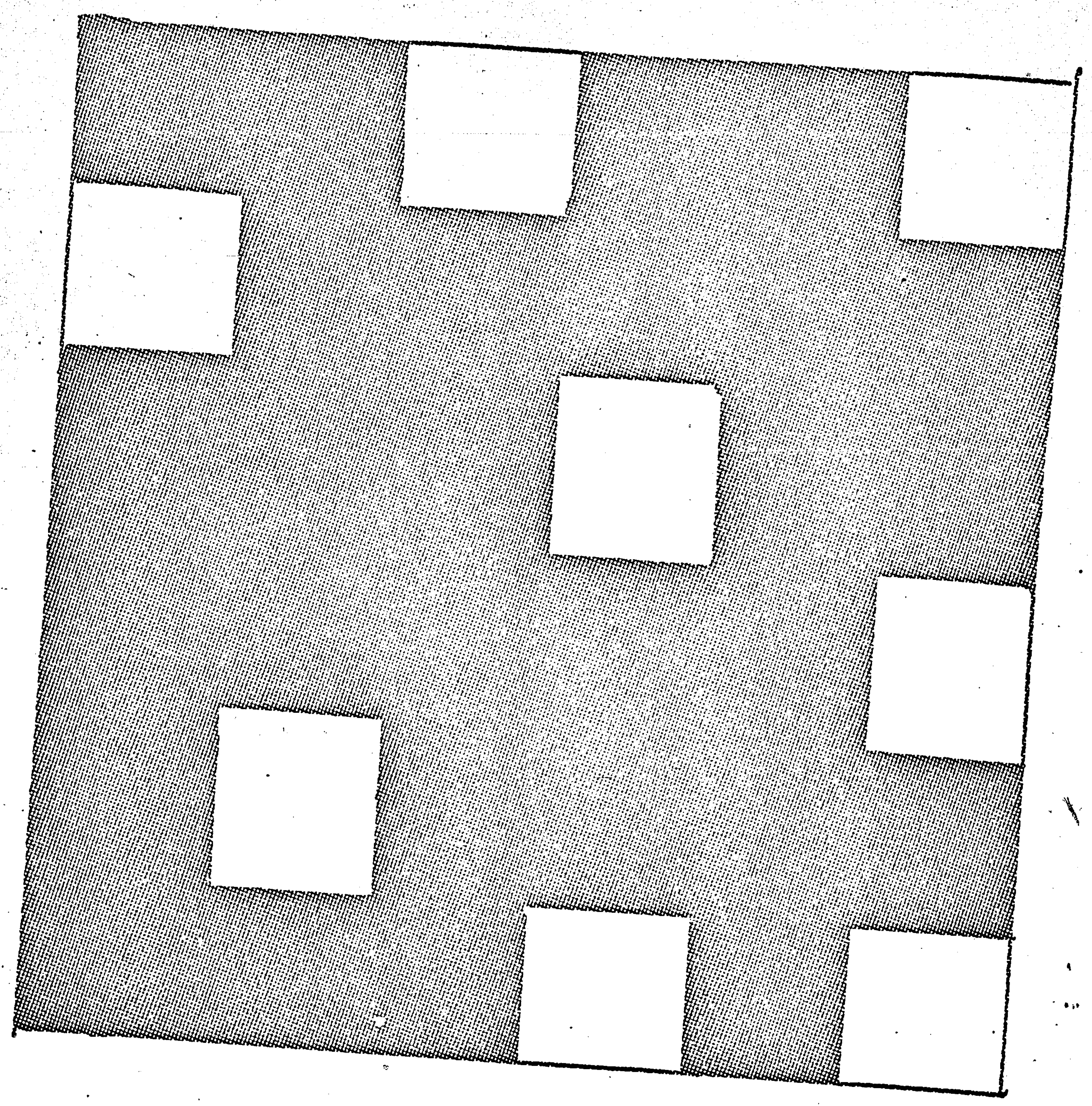

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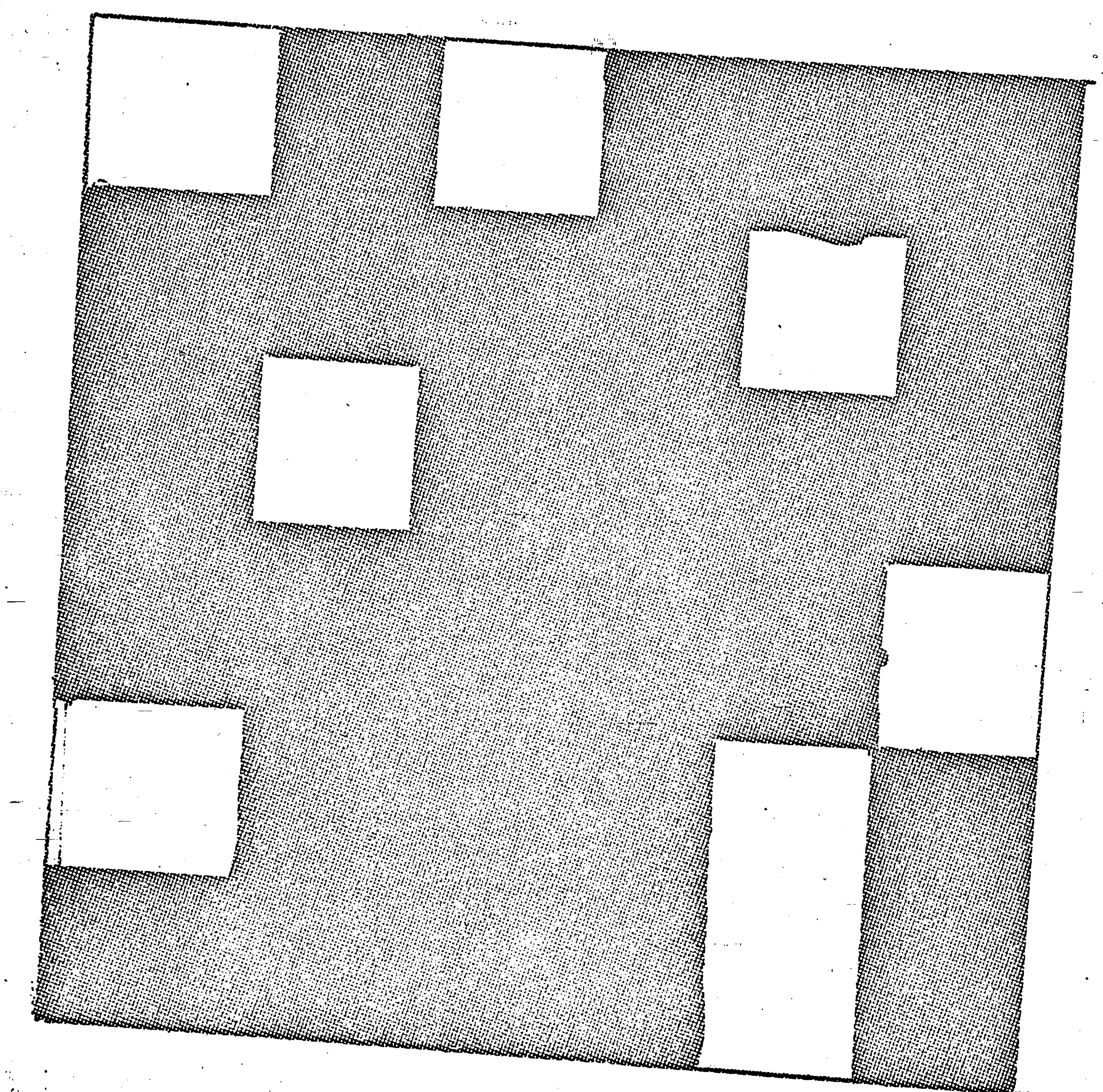

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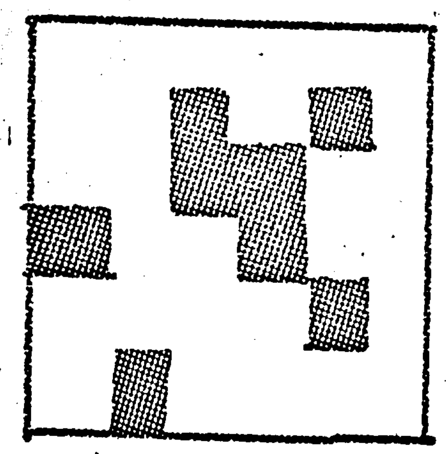

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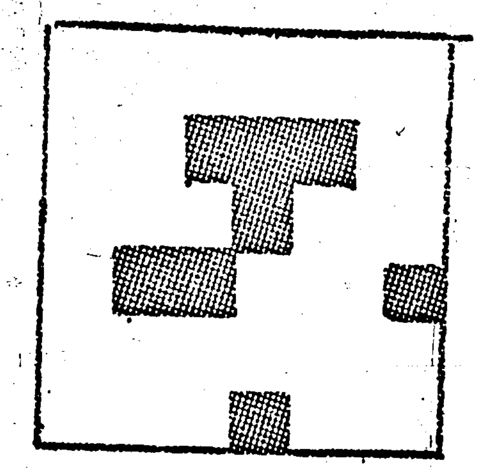

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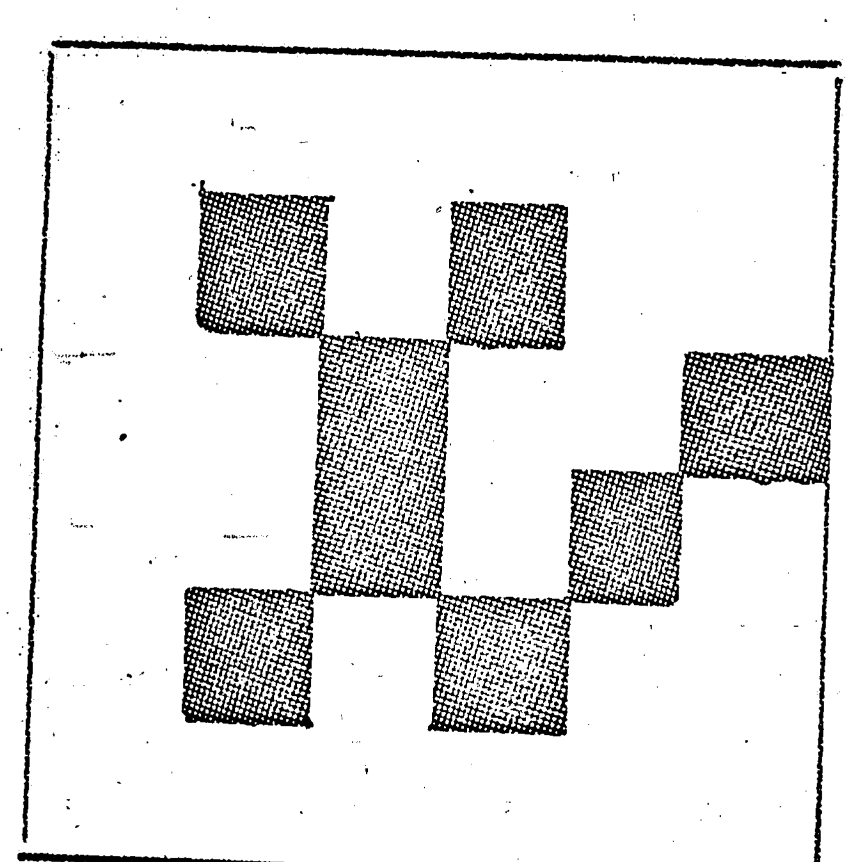

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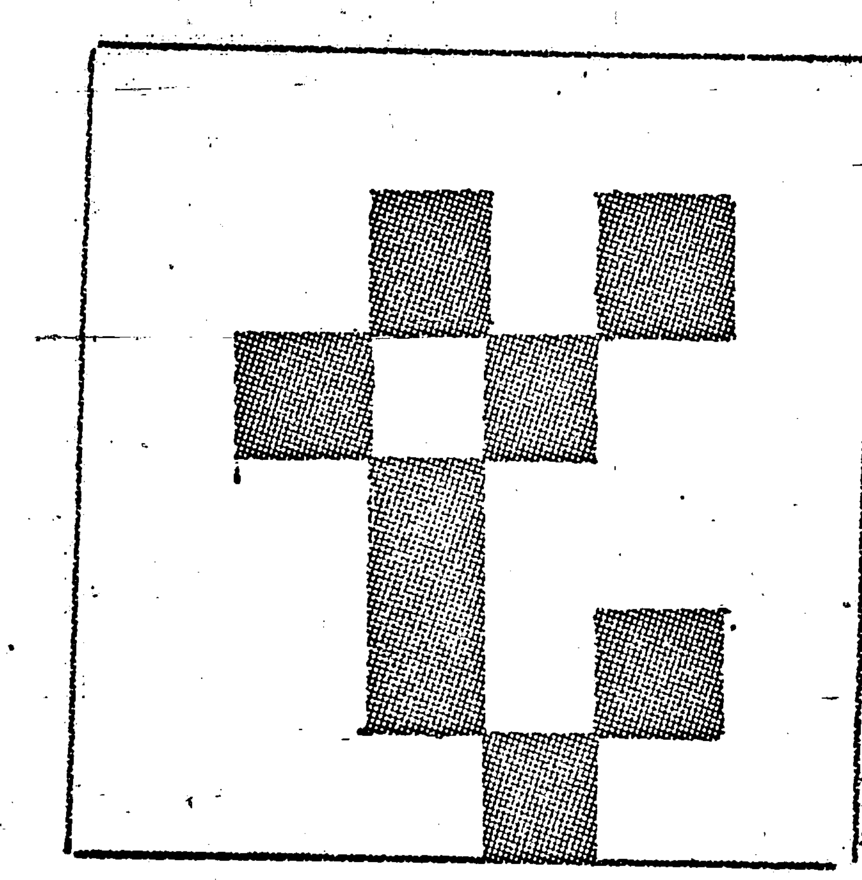
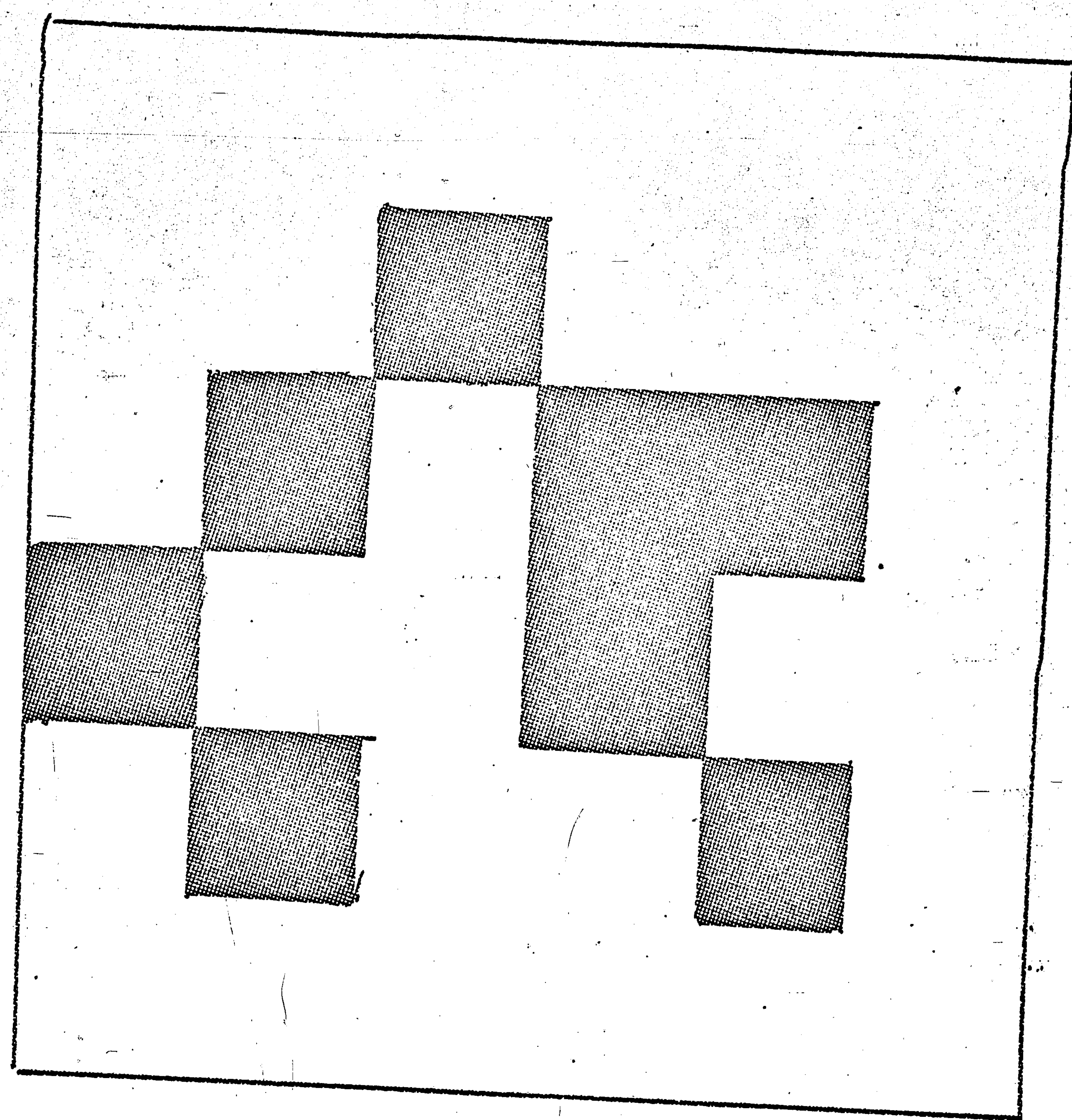
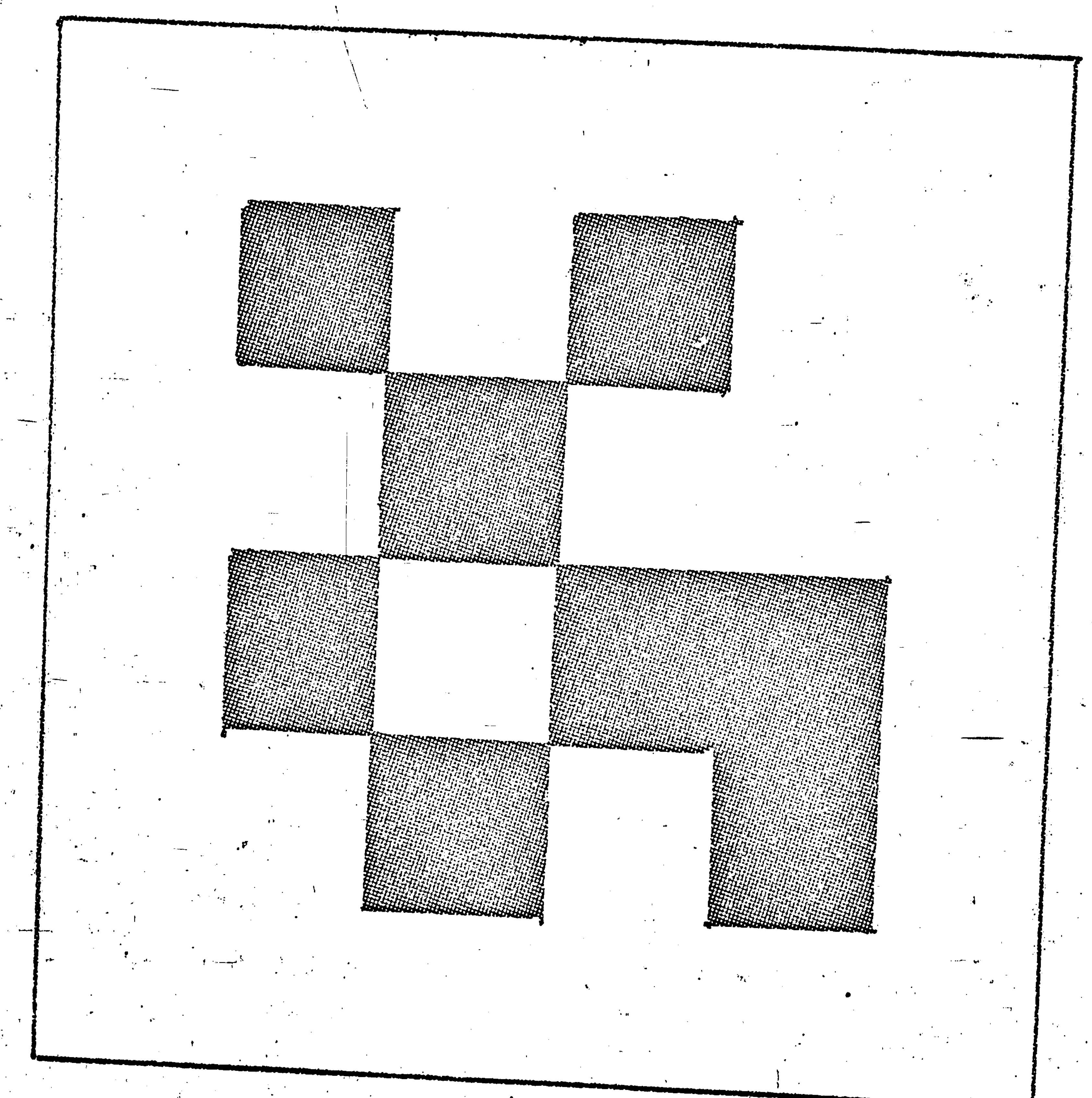


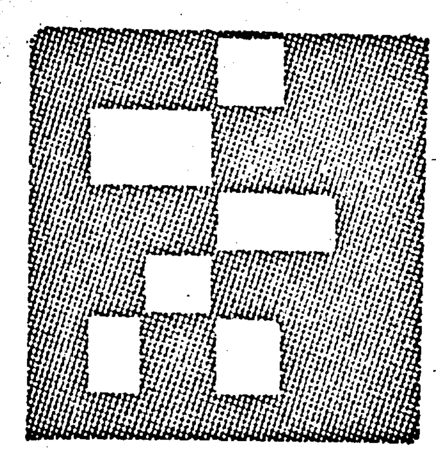
10111



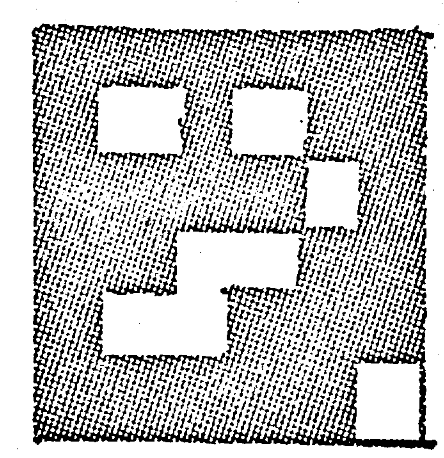
10112



10112



01110



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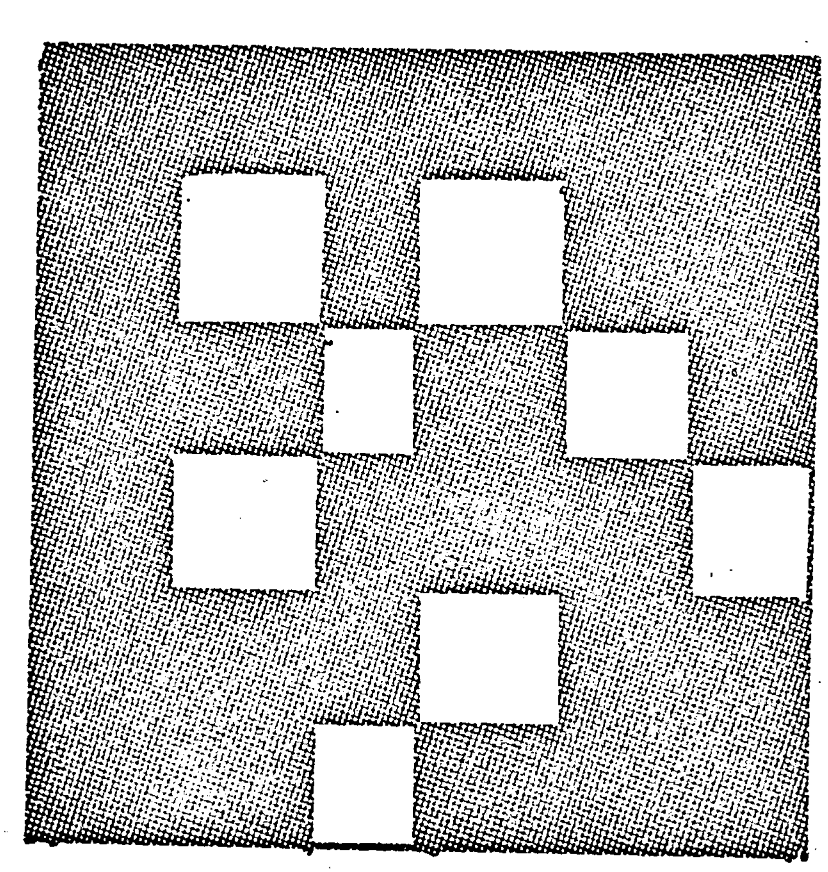

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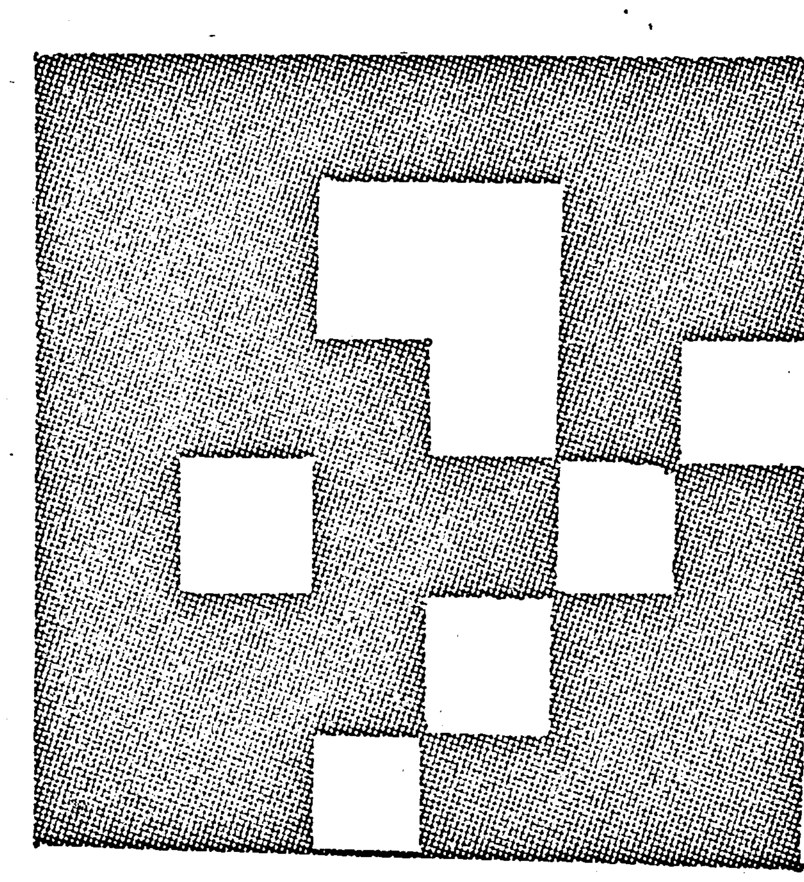

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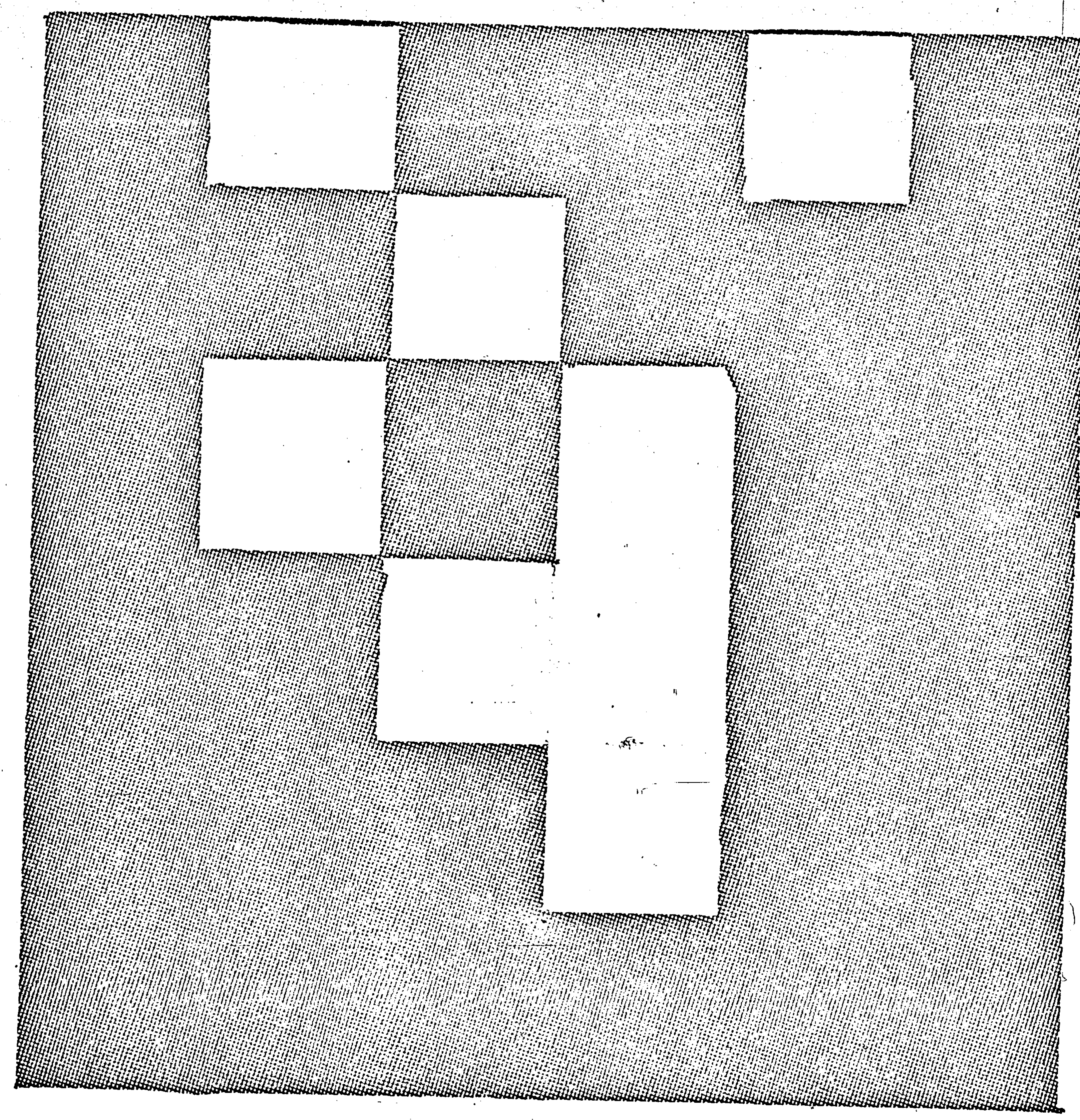

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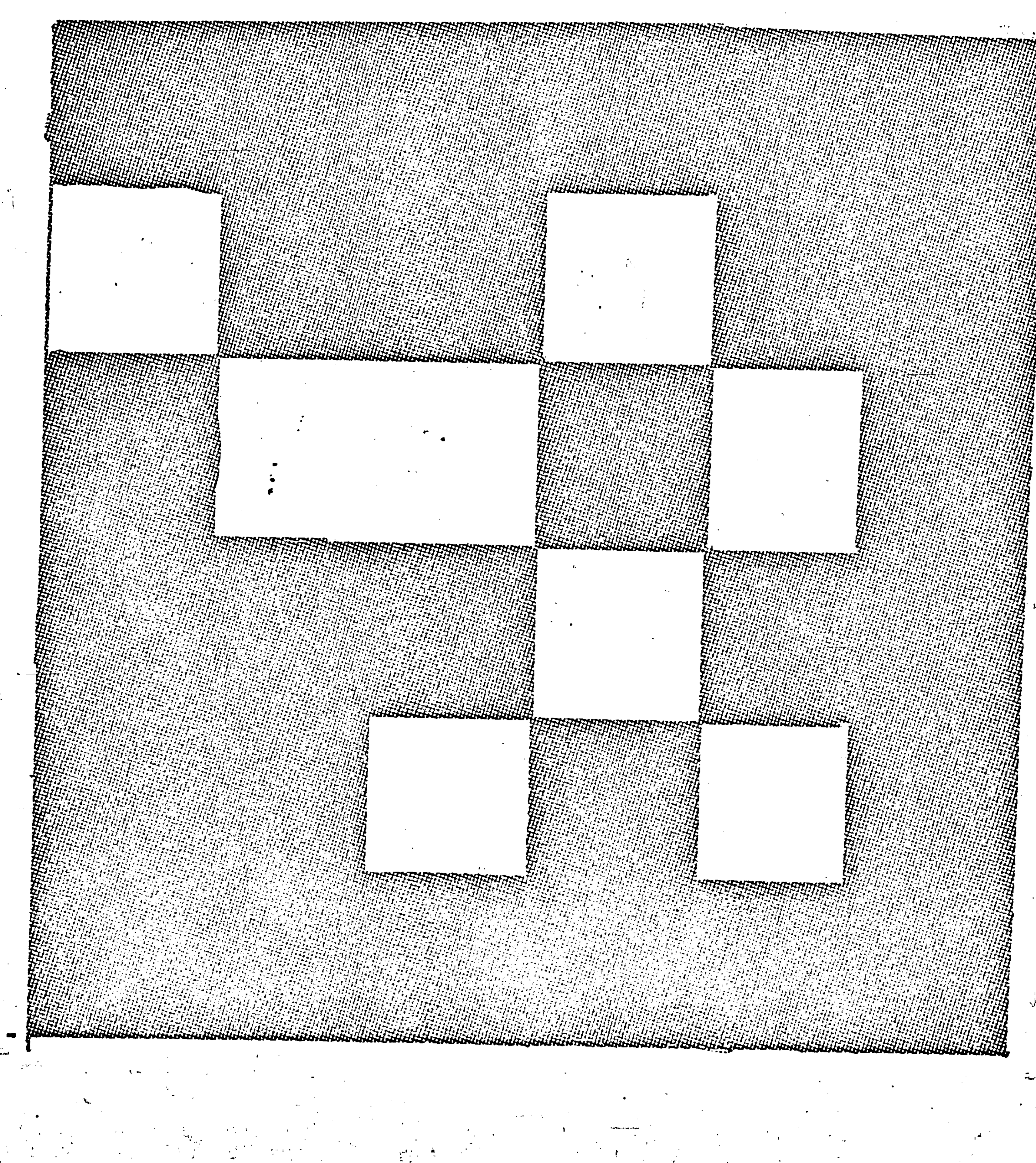

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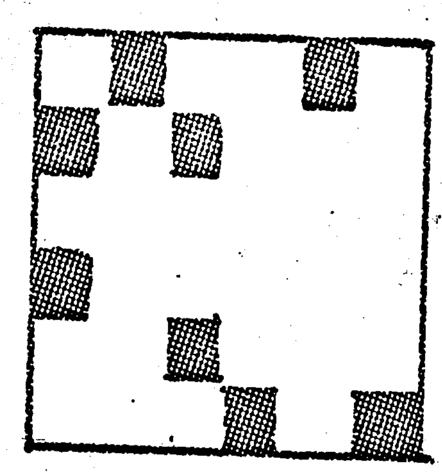

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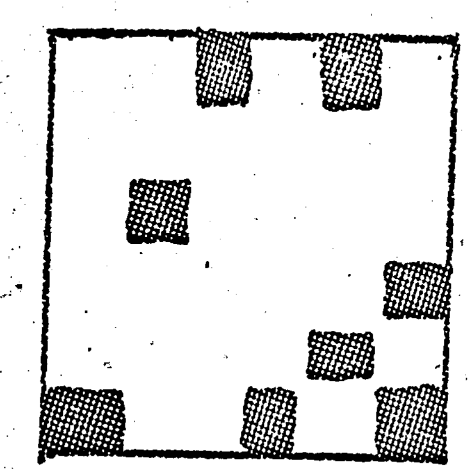

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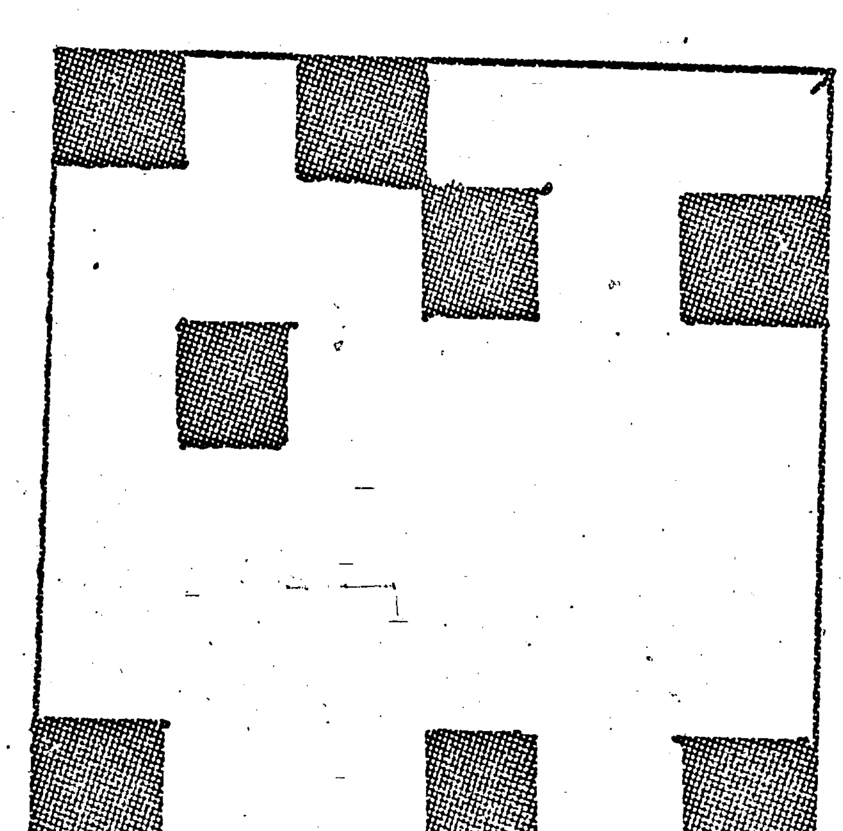

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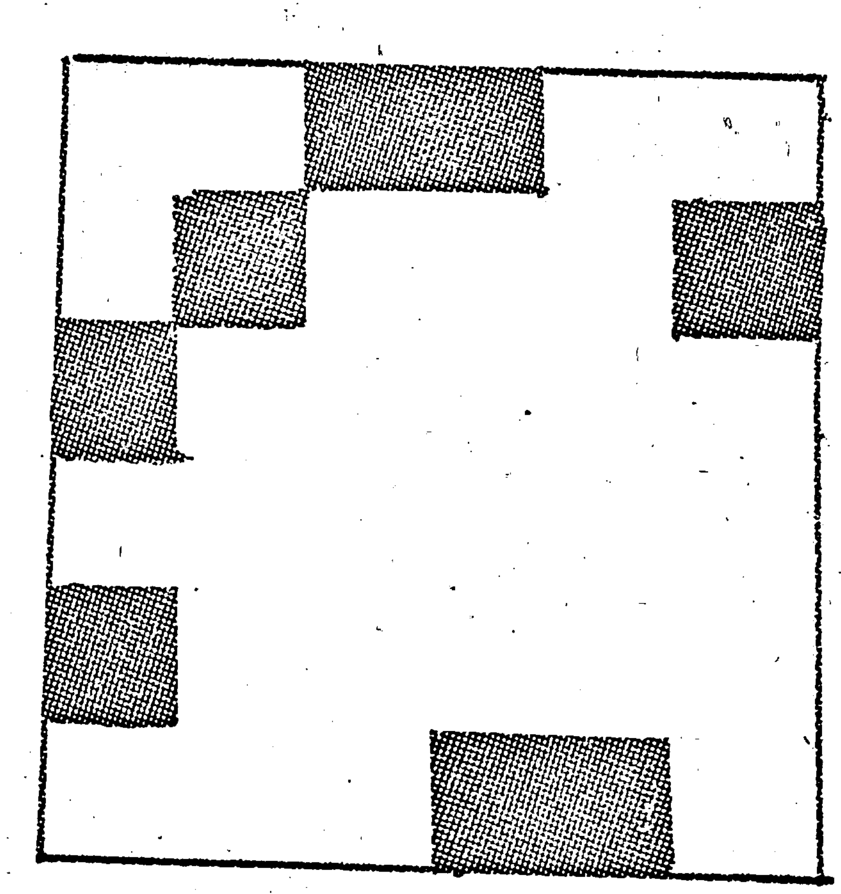

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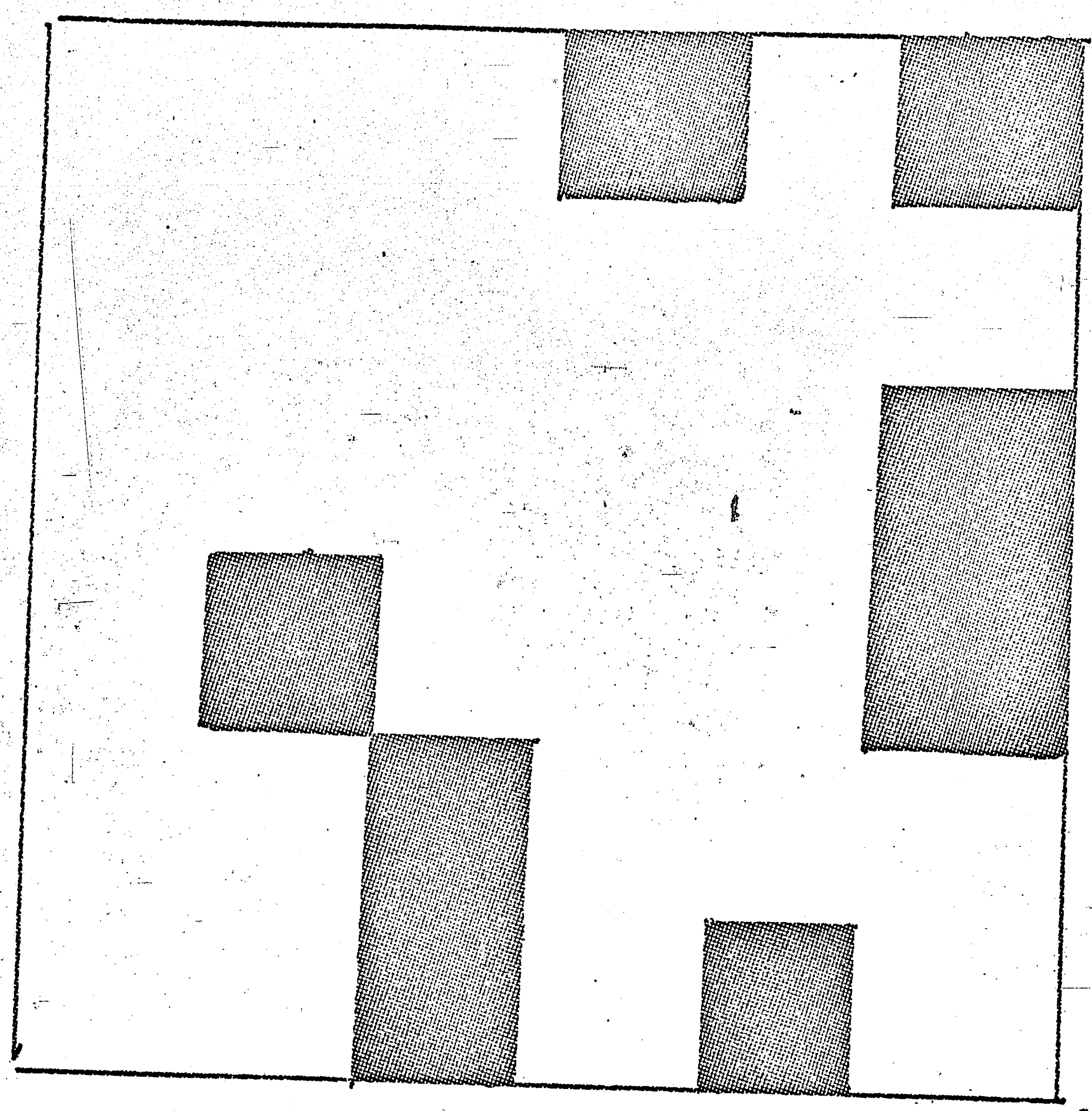

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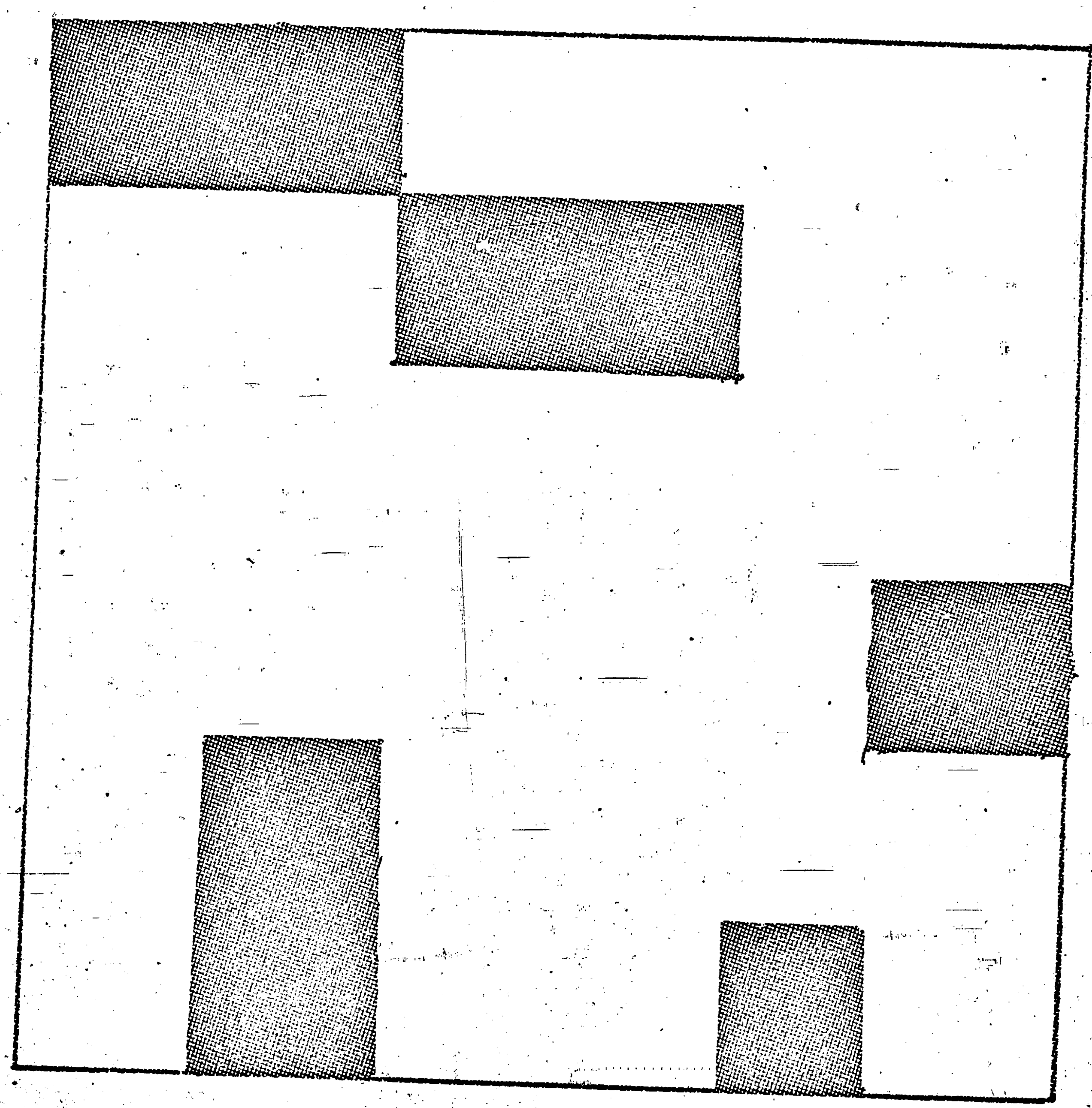

11112

Appendix B

First Trial Data of all subjects for 1st experimental session. The 96 stimuli are arranged in the order given in Appendix A but with 2 stimuli at each level; e.g., stimuli number 1 and 2 represent factorial combination 00000 and 3 and 4, 00001; etc.

	Experiment I										Experiment II									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1	1	1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0
2	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	0	0
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	0	1	1
5	1	1	1	0	0	1	1	1	1	1	1	1	1	0	0	1	1	0	1	1
6	1	1	1	0	1	1	1	1	1	1	0	1	1	1	0	1	0	0	1	1
7	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0
8	0	0	0	1	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0
9	1	0	0	0	0	1	0	0	0	1	1	1	0	1	0	0	0	0	1	1
10	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	1	1
11	1	0	0	1	0	1	1	0	1	0	0	1	1	1	0	0	0	0	1	1
12	0	0	0	1	0	0	0	0	1	1	0	1	1	1	0	0	1	0	1	1
13	1	0	1	1	1	0	1	1	1	0	1	0	1	0	1	1	1	1	0	0
14	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	0	0
15	1	1	1	0	1	0	1	1	1	0	1	0	1	0	0	1	0	0	1	1
16	1	0	1	1	1	1	0	1	1	1	1	0	1	0	0	1	0	0	1	1
17	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1
18	1	0	0	0	1	1	0	1	1	1	0	1	1	1	0	1	0	1	1	1
19	1	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0
20	1	0	0	0	1	1	1	0	0	0	0	1	1	0	1	1	1	1	0	0
21	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1
22	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	1
23	1	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	1
24	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1
25	1	1	1	1	1	1	1	1	1	0	0	1	1	0	1	1	0	0	0	0
26	1	1	1	1	1	1	1	1	1	0	0	1	1	0	1	1	1	0	0	0
27	1	1	1	0	1	1	1	1	1	0	0	1	0	0	0	1	1	0	1	1
28	1	1	1	0	1	1	1	1	1	0	1	1	1	0	0	1	1	0	1	1
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1
30	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	1	0
31	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0
32	1	0	1	1	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	0
33	1	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	1	1	1	1
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35	0	0	0	1	0	0	0	0	1	1	1	1	0	1	0	0	1	0	1	1
36	0	0	0	1	0	1	0	0	0	1	0	1	1	1	0	0	0	1	1	1
37	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	0	0
38	1	1	1	0	0	1	1	1	0	1	0	0	1	0	0	1	1	0	0	0
39	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	0	1	1
40	1	0	0	1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	1	0
41	1	0	1	1	1	1	1	1	1	1	0	0	1	0	0	1	0	0	1	1
42	1	1	1	0	1	1	1	1	1	1	1	0	1	0	0	1	0	1	1	1
43	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0
44	1	0	0	0	0	1	0	0	0	0	1	1	0	0	1	0	1	1	0	0
45	0	0	0	1	0	0	0	0	0	0	1	1	0	1	0	0	1	1	1	1
46	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0	1	1	1	1
47	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0	1	0	1	1

	Experiment I										Experiment II									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
48	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	1	1
49	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0
50	1	1	1	0	1	1	1	1	1	0	0	1	0	1	1	1	1	0	0	0
51	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	0	1	0
52	1	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1	0	0	1	1
53	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	0	0	1	1
54	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	0	1	1	1
55	0	0	0	1	0	1	0	0	0	0	1	1	1	1	1	0	0	0	0	0
56	0	0	0	1	0	1	1	0	0	0	0	1	1	1	1	0	0	1	0	0
57	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	1	1	1
58	0	1	0	0	0	0	0	0	0	1	1	1	0	1	1	0	0	1	1	1
59	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	1	1
60	0	0	0	1	0	1	0	0	0	1	0	1	0	1	0	0	0	1	1	1
61	1	0	1	1	1	1	1	1	1	0	1	0	1	0	1	1	0	0	0	0
62	0	1	1	0	0	0	1	0	1	1	1	0	0	1	1	0	0	1	0	1
63	1	1	1	1	1	1	1	1	1	1	0	0	1	1	0	1	0	0	1	0
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65	1	1	1	0	1	1	1	1	1	0	1	0	1	0	0	1	0	1	1	1
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67	0	0	0	0	0	0	0	0	1	0	1	0	0	1	1	0	1	1	0	0
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0
69	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	1	1	1
70	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0	1	1
71	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	1
72	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1
73	1	1	1	0	1	1	1	1	1	0	0	1	1	0	1	1	1	0	0	0
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76	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	0	1	1
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86	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	1	0	0	0	0
87	1	1	1	1	1	1	1	1	1	0	1	0	1	0	0	1	0	1	1	1
88	1	1	1	0	1	1	1	1	1	0	1	0	1	0	0	1	0	1	1	1
89	1	1	1	0	1	1	1	1	1	0	0	0	1	0	0	1	0	1	1	1
90	1	1	0	1	1	0	1	1	1	1	0	0	1	1	0	1	0	0	1	1
91	0	1	0	0	1	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0
92	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	1	0	0	0
93	0	0	0	1	0	0	0	0	1	1	0	1	0	1	1	0	1	1	1	1
94	0	0	0	1	0	0	0	0	0	0	1	0	0	1	1	0	0	1	1	1
95	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1
96	1	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	1

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VITA

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He graduate from Hazle Township High School, Hazleton, Pennsylvania, in June of 1962. He entered Drexel Institute of Technology, Philadelphia, Pennsylvania, in September of 1962, and graduated from that institution with a Bachelor of Science degree in Electrical Engineering in June of 1967.

In September of 1967, he enrolled in Lehigh University, Bethlehem, Pennsylvania, for graduate study in Psychology. At Lehigh he held a National Science Foundation Traineeship and served as a graduate assistant. He served as an Instructor of Psychology at the Allentown Center, Penn State University.

Mr. Catano is a member of Eta Kappa Nu, Psi Chi and the Society of Sigma Xi Honor Societies. He was a member of the Advanced Study Institute on Human Factors/ Ergonics held in Mondello, Sicily, in the Fall of 1969. He has presented the following paper:

Catano, V. M. and Karsh, E. B. Some Effects of Punishment on Learning and Extinction in an Automated Runbox. Paper presented at the Psychonomic Society, Chicago, Illinois, October 1967.